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Technical Report: NAVTRAEQUIPCEN 80-C-0079

AD A139679

SUBMARINE ADVANCED REACTIVE TACTICAL
TRAINING SYSTEM (SMARTTS)

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SMARTTS FINAL REPORT (July 1980 - September 1982)

TRAINING EQUIPMENT CENTER
ORLANDO, FLORIDA 32813

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| REPORT DOCUMENTATION PAGE | READ INSTRUCTIONS BEFORE COMPLETING FORM |
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| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
|---|---|---|
| NAVTRAEQUIPCEN 80-C-0079 | AD·A139679 | |

| 4. TITLE (and Subtitle) | 5. TYPE OF REPORT & PERIOD COVERED |
|---|---|
| SUBMARINE ADVANCED REACTIVE TACTICAL TRAINING SYSTEM (SMARTTS) | Final Report July 1980 - September 1982 |
| | 6. PERFORMING ORG. REPORT NUMBER EA-82-U-076 |

| 7. AUTHOR(s) | 8. CONTRACT OR GRANT NUMBER(s) |
|---|---|
| Thomas J. Hammell | N61339-80-C-0079 |

| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
|---|---|
| Eclectech Associates, Inc. North Stonington Professional Center North Stonington, CT 06359 | 8004 |

| 11. CONTROLLING OFFICE NAME AND ADDRESS | 12. REPORT DATE |
|---|---|
| Naval Training Equipment Center Orlando, FL 32813 | |
| | 13. NUMBER OF PAGES 127 |

| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) | 15. SECURITY CLASS. (of this report) |
|---|---|
| | UNCLASSIFIED |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

N/A

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

None

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Submarine Advanced Reactive Tactical Training System (SMARTTS) is a preprototype training subsystem that has been installed on the 21A41A submarine combat system trainer, located at the ASW Training Center, Norfolk, Virginia. SMARTTS represents the initial application of training assistance technology to an existing large scale trainer in the operation training environment. SMARTTS embodies characteristics designed to improve the effectiveness of training in complex simulator-based training systems by enhancing the training process. (Continued)

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## ABSTRACT (CONTINUED)

The SMARTTS characteristics address the instructor, the trainees, and the training system management. They provide the instructor with added capabilities to develop training exercises, conduct the training process, monitor the performance of the trainees, and provide specific instructional guidance to the trainees. They assist the trainees by providing a wide range of relevant information via visual displays prior to, during, and following participation in a scenario on the trainer. A basic level of management support is provided in the form of long-term data collection, and the information for development and structuring of training programs.

Major capabilities developed as part of the SMARTTS training subsystem include: (a) automated assistance for exercise development; (b) automatically generated and recorded performance indicators; (c) visual feedback displays for presentation of performance indicators and tactical variables, in the attack center and in the classroom; (d) alternative tactics capability for rapid generation of alternative sets of actions; (e) automatic instructor cues based on scenario events; (f) student entered time flag, automatically recorded, to indicate points of concern during replay; (g) automatic interactive target providing computer control of a target platform, responding to ownship actions; (h) an exercise library containing a large number of exercises, each of which can be automatically loaded and started in the system; (i) simultaneous and independent operation of classroom and attack center subsystems; (j) fast-time and real-time classroom simulation subsystem for support of pre-scenario and post-scenario briefing sessions (e.g., feedback); (k) exercise playback presenting a wide variety of tactical variables and performance indicators as occurring during the scenario; (l) an instructors console located near the fire control party in the attack center, providing a wide range of monitoring and control capabilities for the instructor; (m) an instructors handbook addressing the development and conduct of an effective training process; and (n) various documentation supporting the development of SMARTTS and its operation. This report provides a summary overview of SMARTTS, including its development and resultant characteristics.

A research and development plan has been assembled to recommend the next stages of effort appropriate for the continued development of training assistance technology.

EXECUTIVE SUMMARY

The Submarine Advanced Reactive Tactical Training System (SMARTTS) has been developed as the "training subsystem" of the 21A41A submarine combat system trainer. The SMARTTS design is that of a generic training subsystem, which combined with the traditional simulation subsystem and associated tactical equipment, form the training device. SMARTTS embodies a variety of training-related features that are essential to an effective training process. The generic capabilities embodied in SMARTTS are required on every training device, to a greater or lesser extent, and should be tailored to the particular aspects of each training situation.

The SMARTTS concept is the embodiment of training assistance technology (TAT) in the simulator-based training device, as an integral part. Whereas the typical sophisticated military training device is actually only a complex simulator, doing a relatively good job of copying the operational environment, the training device with SMARTTS actually has capabilities designed to address the training process. The training device is more than just a simulator; it should provide the trainees with more than just experience; it should provide automated capabilities to assist the instructor and interface with the trainees, thus enhancing the training process. The current state of training technology reveals a wide range concepts (e.g., feedback) critically affecting the training process. The complexity of military systems and operations precludes instructors from manually taking advantage of many aspects of current training technology. The computer-based processing and interface capabilities currently available in most simulator-based training devices, however, enable the automation of many of these training technology concepts. Hence, the training assistance technology embodied in SMARTTS is "good generic" training technology adapted to and integrated with the inherent processing capabilities of the sophisticated training device. These training process-related capabilities make up the training subsystem of the training device to augment the traditional simulation subsystem.

The essence of SMARTTS is its capability to collect and generate a variety of information pertinent to the tactical training problem, and to display various combinations of that information on the instructor's console, classroom large screen display and the attack center overhead monitors at appropriate times during the training process. Substantial support capabilities are resident in the system to manipulate the information in the various ways required during the training process. It should be noted that the preprototype SMARTTS does not incorporate all of the possible characteristics recommended in earlier analytic studies. Rather, the preprototype unit includes those characteristics essential to the SMARTTS concept of training assistance technology which were feasible within budget and time constraints. It does provide the basic structure for implementing additional characteristics or application to other training situations.

The 21A41A SCST, including the SMARTTS addition, addresses the training of combat teams of the SSN 688 class submarine, using the MK117 fire control system. The SMARTTS preprototype installed at Norfolk, Virginia is capable

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of either standalone operation or operation integrated with the traditional 21A41 SCST in support of attack center training and classroom training. SMARTTS hardware consists of an instructor's remote console (IRC) located in the attack center to monitor and control various aspects of the problem, and two overhead CRT displays in the attack center. A similar instructors console is located in the adjacent classroom. It controls a large screen display in the classroom. Both the classroom and attack center subsystems can be operated prior to, during, and following an attack center exercise. The intention of this design is to support a variety of tactics training needs across multiple courses and levels of trainees.

Performance indicators have been developed to evaluate the trainee's responses and provide corrective feedback. Each performance indicator addresses a specific aspect of the tactical situation; examples of PIs are probability of counterdetection, and target motion analysis initial range estimate. The basis of the SMARTTS effectiveness as a training device is its data collection function. It records the state of the system, trainee actions, and instructor inputs for later analysis and feedback. Based upon the performance indicators and other relevant recorded data, feedback information and associated displays are generated for presentation to the trainee prior to, during, or following an attack center exercise.

While the SMARTTS design approach is to complement, rather than replace the primary simulation of the training devices, there are two data generation functions within SMARTTS which provide simulation. First is the Automatic Interactive Target (AIT). The AIT is a computer controlled adaptive target model. Its decisions and actions are executed as a consequence of the trainees' ownship action, thus providing a realistic simulation of enemy actions. The second simulation function consists of a set of models used in the standalone mode to support classroom investigation. Although not as sophisticated as the main simulation models, they provide necessary and reasonable simulation for alternative tactical analyses and scenario preview operations.

SMARTTS has been designed to provide both standalone operation and integrated operation with the simulation subsystem of the training device (i.e., attack center). While the specific information generated and presented via SMARTTS pertains to submarine tactics training, the basic design of SMARTTS is generic and capable of being applied in a variety of training applications.

The SMARTTS preprototype provides capabilities in support of a wide range of instructor functions, provides capabilities to assist the instructor in achieving an effective trainee interface with the training process, and provides rudimentary capabilities to assist in training system management. These capabilities support the four major functions of the training process: (a) exercise development, (b) monitor and control of the real-time training scenario, (c) instructing the student, and (d) training system management.

SMARTTS represents the initial application of TAT to an operational training device. For this reason it is a preprototype unit, and likely to require refinement as it is used. The software structure is flexibly

designed to permit evolution (i.e., reasonable modification of performance indicators, display formats, models, AIT actions, and so on). Furthermore, SMARTTS has opened a major area of development -- training assistance technology. Hence, a research and development plan has been developed to map subsequent TAT and SMARTTS research and development efforts. The Recommendations Section (V) of this report identifies 101 issues for further investigation and development, associated with three areas of work: (a) 21A41A Site Work; (b) TAT Research and Development; and (c) Other Areas. Recommendations are also given regarding additional dimensions and aspects related to each issue.

The next iteration of this research and development plan should key on those issues that have been given the highest priority (i.e., number one). Several of these are associated with very low cost, and hence should be addressed immediately. Others have substantially higher associated costs, and should be given priority in the long-term. It may also be desirable to address issues that have a medium priority (i.e., number two) with associated low costs, since these are likely to provide cost/effective results in the near-term.

The initial research and development emphasis forthcoming from this plan should be focused on site work, since it is imperative that SMARTTS be responsive to site needs as originally designed. This will not only improve the cost/effectiveness of the ongoing operational training on the 21A41A SCST, but will also assist in obtaining meaningful user evaluation of the SMARTTS preprototype (i.e., the initial installation of SMARTTS was intended to evolve during the test and evaluation period by improving the PIs, feedback displays, etc.). The training assistance technology addressed in the SMARTTS preprototype and those issues addressed in this research and development plan map out the training subsystem of the training device. The products emanating from investigative efforts in this area will have substantial impact on the cost/effectiveness of all training devices and systems.

PREFACE

This report is the final document of the SMARTTS preprototype development. SMARTTS represents the culmination of many years of research and development, resulting in the development of a preprototype application of Training Assistance Technology. This preprototype, although not fully evaluated, has already ushered in a new era in training device design, insuring that a training subsystem will be carefully considered in the design of every training device. The SMARTTS preprototype, and its effective implementation, is due to the cohesive efforts of the three major elements of the project team -- the ASW Training Center (user), the U.S. Naval Training Equipment Center (procuring agency), and Eclectech Associates, Incorporated (contractor). It is fitting, therefore, that those individuals having major contributions to the accomplishments of this program be recognized.

The training assistance technology concepts embodied in the SMARTTS preprototype are the result of more than a decade of research and development efforts. The initial conceptual work leading to the development of training assistance technology was achieved in the late 1960's and early 1970's through work with the SUBSCOL staff, New London, Connecticut. This work has more recently culminated with the development of the preprototype SMARTTS at the ASW Training Center in Norfolk, Virginia. Many individuals have contributed in various ways to the training assistance technology concepts, the various research efforts, and the development of the SMARTTS preprototype. It is beyond the scope of this report to document the contributions of all participants. However, several individuals have made exceptional contributions to the SMARTTS preprototype. These are noted below.

The ASW Training Center in Norfolk was an essential element of the SMARTTS development. Their willingness to receive the preprototype system, their assistance in providing us with many useful recommendations regarding specific design aspects, and their substantial assistance in the actual installation was invaluable to the project. Special acknowledgement is due LT R. Zeller, and LT S. Ellis, both former department heads, submarine tactics training; LT H. O'Bryant, department head, submarine tactics training; LTjg R. Dulin, department maintenance officer; STSC Rich, TDCM J. Wood, and STSC Hafele. These individuals and their staff provided exceptional assistance to the project throughout its duration, and of greatest importance, enthusiastic support to the use of new technology to improve submarine tactics training.

The second major element of the SMARTTS team was Code N71, U.S. Naval Training Equipment Center. Mr. William P. Lane, director of the Human Factors Laboratory, was a part of the initial conceptual development of Training Assistance Technology, and a staunch fighter for its development and application to submarine tactics training. His tenacity assured its full development. LT Thomas N. Crosby, SMARTTS acquisition director, was the primary driving force behind the preprototype development. As the Navy's representative he led the SMARTTS team. Mr. W. Lunceford was the NTEC engineering representative. He provided exceptional assistance in

helping to assure the project met its technical goals. Dr. R. Reynolds assisted LT Crosby in overseeing the project, and assumed the duties of acquisition director after the latter's transfer.

The third and final major element of the SMARTTS team is Eclectech Associates, Incorporated, and the many individuals who have contributed substantially of themselves to the many aspects of the project. Their collective contribution is SMARTTS! The key individuals were Dr. G. Lloyd, software design; Mr. F. Ewalt, modeling and training; Mr. M. Hayes, hardware system design; and Mr. R. Friedmann, site liaison, modeling, and training. These were assisted by Mr. S. Weinstein, software; Mr. J. Bennett, software; Mrs. P. Sherrard, AIT software; Mrs. P. Rabe, software; Mr. W. Henry, training; technical publications staff; Mr. R. Gomes, hardware; Mrs. S. Shannon, secretary, Ms. J. Fryer, secretary; and Mrs. V. Pittsley, training.

SMARTTS is the result of a close and strenuous relationship between the user, procuring agency, and contractor.

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SECTION I

INTRODUCTION

The Submarine Advanced Reactive Tactical Training System (SMARTTS) has been developed as the "training subsystem" of the Submarine Combat System Trainer (SCST), the primary training device employed to achieve submarine crew tactical proficiency. The purpose of SMARTTS is to provide a variety of training assistance technology (TAT) capabilities to the SCST to substantially enhance the effectiveness of the tactical training process. SMARTTS has been designed to provide a range of generic capabilities which can be tailored to meet the needs of differing training applications. The preprototype version of SMARTTS, which is installed on the 21A41A SCST at the Fleet ASW Training Center, Norfolk, Virginia, encompasses a set of TAT capabilities which have been specifically tailored to address individual operator and combat team training requirements associated with the SSN MK117 Fire Control System. SMARTTS is currently undergoing evaluation in this applied operational training environment.

## 1.1 TACTICS TRAINING BACKGROUND

The U.S. Navy Submarine Force has been experiencing accelerated transition to significantly improved, although increasingly complex, weapons and tactical command and control systems for both SSNs and SSBNs. The MK116, MK117, and MK118 fire control systems, and the AN/BQQ-5 sonar system are examples of the rapidly developing combat system capabilities, bringing attendant increases in potential weapon system effectiveness and operational complexity. These technological advances are matched by expanding submarine mission roles and tasks in tactical and strategic warfare, and other classified operations. The developing cruise missile vertical launch capability for the SSN 688 class submarine is one example of a potentially substantial change in the mission of the attack submarine. Enhanced operational performance of weapons, fire control, sonar, periscopes, electronic support measures, and other sensors, together with advanced ship characteristics, places heavy emphasis on responsible tactical command and control. High speed digital data processing, coupled with computer analysis of multiple sensor inputs requires highly developed operator visual and interpretive skills. These skills must be supported by the operator's ability to make complex tactical decisions. It comes as no surprise, therefore, that these operational system developments have been placing increasing demands on submarine tactical and operational training to promote increased operational proficiency and readiness.

The overall submarine tactics training system, whether providing formalized team training in shore-based attack centers or individual on-the-job training at sea, principally exists to support submarine force operational readiness. Submarine combat system trainers for SSN and SSBN crews are located at all major submarine operational training centers. Simulation methodology and equipment retrofits to these devices provide the latest in onboard equipment developments, recreating the submarine attack

center and its engagement with hostile forces. Collectively, these SCSTs represent the primary component of the submarine tactical training system.

Submarine tactics training presently satisfies a wide range of requirements, from the submarine officer basic, indoctrination, and advanced courses (SOBC, SOIC, and SOAC), through advanced levels in the prospective executive officer (PXO) and the submarine force commander's prospective commanding officer (PCO) courses. Training within these courses spans individual through team contexts. Extensive refresher and predeployment training programs are also conducted using the SCSTs. Advanced training assistance technology is required for these SCSTs to enhance the training process.

## 1.2 TAT BACKGROUND

An instructor station has traditionally been a part of every simulator/training device. However, it has often been a misnomer consisting of little more than an operator's station for the controlling of the sophisticated simulator. Relatively few capabilities have typically been provided as part of the instructor station to enhance the instructional process (e.g., provide feedback to the trainees). The necessary technology has existed, both in the form of hardware/software capabilities and training/instructional techniques, for the development highly cost effective training tools integrated into the training device to enhance the instructional process. Thus, a "bonafied" training subsystem embodying TAT capabilities can and should be a part of every training device.

The General Accounting Office, in their report to Congress concerning "How to Improve the Effectiveness of U.S. Forces Through Improved Weapon System Design" (1981), focused on the importance of the operator to the overall effective functioning of the weapon system. They estimated that human errors account for at least 50 percent of the failures of major weapon systems. They further subdivided these failures into operator skill level and proficiency limitations, among other factors. Their findings attribute the operational and readiness problems to the increasing complexity of modern weapon systems. An important issue evident from this investigation is the need for improved training as one means of improving operator proficiency and reducing operator error. This points to the need for more effective training systems, of which the training subsystem is a major contributing part. Also, the complexity of the training device and training system is increasing in parallel with that of operational systems. Hence, more effective human factors design of the training system from an instructional process standpoint is required. Both of these findings point to the obvious requirement to design the training system with particular regard for the instructor and trainee interfaces.

The problem of developing a more effective training system is not really new, since the training community has always been concerned with the effectiveness of instruction. The predominant emphasis in the design of training devices and systems in recent years, however, has been placed on the engineering aspects, such as concern over adequate simulation fidelity

and the technology to achieve that fidelity. Although cost-effective fidelity should be a major issue, proportionate emphasis should be given to the other training-related aspects of the training device and system. Recent research (Hammell, Gynther, Grasso, and Gaffney, 1981) has shown that instructor characteristics may have a greater impact on the effectiveness of training then substantial differences in simulator fidelity. The importance of this finding is that the instructor typically embodies most of those nonsimulation characteristics of the training device and training system (e.g., exercise design, monitoring of student performance, and student feedback). Substantial gains in training effectiveness, therefore, should arise by providing TAT capabilities that directly address the training process. The training device, therefore, should be more than just a simulator. It should provide TAT capabilities to directly support the instructor and trainee interfaces, and hence directly support the training process.

The advanced training concepts embodied in TAT, and those included in SMARTTS, directly stem from two studies sponsored by the Naval Training Equipment Center (Hammell, Sroka, and Allen, 1971; Hammell, Gasteyer, and Pesch, 1973). These studies investigated the then current and future needs of submarine tactics training devices. A variety of recommendations were forthcoming, addressing individual and team training needs at basic through advanced levels. The recommendations addressed new training devices, as well as modifications to existing training devices. The 21A series submarine combat system trainers were in use at the time, but typically had few capabilities built-in to assist the instructor in conducting the training process. The recommended modifications to the SCSTs included:

a. the need for generation of objective performance indicators based on the already generated scenario parameters,

b. a variety of feedback displays to provide information to the students concerning various aspects of the exercise scenario and the performance indicators,

c. an instructor's console that can provide a range of trainee and scenario monitoring and control capabilities,

d. instructor cues automatically generated by the device,

e. an automatic interactive target controlled by the computer and freeing the instructor from continuous activity of this type,

f. a long-term data analysis capability to continually evaluate and upgrade the effectiveness of the training process and training system,

g. an alternative tactics capability to enable rapid investigation of alternative ownship and target actions in the classroom.

The SMARTTS preprototype operating today is largely made up of generic training assistance technology capabilities that were recommended as part of these earlier investigations, and refined and tailored to the specific application of the preprototype.

These early requirement studies were followed-up by a series of research and development efforts sponsored by the Naval Training Equipment Center to develop a laboratory subset of TAT capabilities that could be evaluated, to conduct laboratory evaluations of the TAT training effectiveness, and to develop a plan for the eventual installation of a laboratory training subsystem integrated with one of the submarine combat system trainers (Pesch, Hammell, and Ewalt, 1974; Hammell, Pesch, Ewalt and Rabe, 1976; Hammell, Manning and Ewalt, 1979). As a part of these investigations a laboratory version of a subset of the MK81 Weapons Control Console (i.e., a major operator interface unit in the MK117 fire control system) was developed, with associated simulation models (e.g., ownship and target maneuvering characteristics, ownship and target sensor characteristics, environmental characteristics) and several major TAT capabilities (e.g., performance indicators, feedback displays). The potential of TAT to substantially improve the effectiveness of the submarine tactics training process was indicated in a laboratory investigation with this device, training active duty submarine officers from Submarine Group Two and SUBSCOL. The intention, as a result of this empirical investigation, was to install the laboratory-type TAT onto an existing SCST and evaluate their training effectiveness in the operational training environment.

As a result of the earlier requirement studies and this series of laboratory investigations, the need for TAT to support the complex submarine tactics training process, and the ready availability of technology to achieve these capabilities, became evident to many in the submarine tactics training community. Callan, Kelly, and Nicotra (1978) integrated several performance indicators and feedback displays into the 21A40 SCST in San Diego. Their empirical investigation in applied submarine tactics training verified the need for, and potential effectiveness of, TAT for submarine tactics training integrated with the SCSTs. The Submarine Advanced Reactive Tactical Training System (SMARTTS) program emerged as a result of these investigations indicating substantial training effectiveness gains resulting from TAT, the ready availability of hardware/software to achieve the TAT capabilities, and the support shown by the submarine tactics training community.

The SMARTTS program was initiated to develop a comprehensive preprototype SMARTTS training subsystem as a part of an existing SCST, for the purpose of evaluating the effectiveness of TAT in operational submarine officer tactics training. The SMARTTS preprototype implementation was directed specifically at training the fire control party of an SSN 688 class fast attack submarine, using the MK117 fire control system. The program began with an extensive front-end analysis, extending the earlier determined training requirements and research findings to the development of a set of specific training device and training system characteristics to support the objective training. This front-end analysis laid out a set of specific TAT characteristics recommended in support of submarine officer tactics training utilizing the SCST. The potentially most effective characteristics recommended by this analysis were then designed as the preprototype version of SMARTTS for installation in the 21A41 SCST at the Fleet ASW Training Center in Norfolk, Virginia (note, the 21A41 SCST with SMARTTS is designated the 21A41A). The preprototype SMARTTS was developed and installed, and is currently being used in submarine officer tactics training. The

effectiveness contribution of SMARTTS to submarine officer tactics training is currently being evaluated by the Navy. Preliminary evaluation by the Navy's submarine tactics training fleet project team has indicated approval and support for the preprototype SMARTTS TAT capabilities. The final evaluation of SMARTTS is expected to occur after it has been in operation for 6 months to 1 year.

The remainder of this report summarizes the developmental approach for implementing the SMARTTS preprototype; provides an overview of the SMARTTS hardware, software, and training characteristics; and presents a comprehensive research and development plan recommending work to follow the preprotoype SMARTTS installation of TAT. It is essential that the preprototype SMARTTS be modified as it is used and evaluated, to improve the training effectiveness value of its characteristics and enhance training. The continual evolution of the SMARTTS characteristics is a fundamental concept in its design, and necessary to insure substantial training gains as training needs and tools change.

SECTION II

DEVELOPMENTAL APPROACH


A systematic design approach was followed in the development of the SMARTTS preprototype, similar to that of the Instructional Systems Development (ISD), Systems Approach to Training (SAT), and Training System Analysis (TSA) approaches. It began with an extensive front-end analysis establishing the individual and team behavior of members of the fire control party, identifying training objectives, and resulting in the identification of specific training system characteristics. The resulting "Type A Specification" (i.e., functional specification) formed the basis for the development of the specific SMARTTS preprototype features. The hardware and software development of the preprototype unit followed, with SMARTTS installed on the 21A41A submarine combat systems trainer in Norfolk, Virginia. Prior to installation of SMARTTS, a plan was developed for the training effectiveness evaluation of the SMARTTS preprototype. Control group data was collected on the 21A41 SCST as part of the planned evaluation prior to beginning the installation of SMARTTS. The control group data provided information relevant to the effectiveness of the traditional training device (i.e., without SMARTTS). The plan was, although not yet carried out, to empirically evaluate the training effectiveness of SMARTTS by comparing the control group performance resulting from traditional training with the performance of crews trained under the SMARTTS-modified system.

The front-end analysis and the control group data collection efforts are summarized in the remainder of this section. The SMARTTS preprototype developmental effort, in terms of the approach to development of the hardware, software and training materials, is not addressed in this report. This developmental effort followed a standard engineering design and manufacturing approach. Details relating to the phases of this development are contained in the various documents generated throughout the effort (see Appendix C). A summary of the preprototype SMARTTS characteristics, however, are presented in the next section of this report (Section 3, SMARTTS Description).


## 2.1 FRONT-END ANALYSIS


The front-end analysis conducted to identify the SMARTTS TAT characteristics was traditional in that it followed a systematic approach beginning with the identification of trainee behavior, and leading to the identification of specific functional characteristics of the training system. Additionally, the front-end analysis investigated alternative hardware and software approaches prior to arriving at the recommended SMARTTS characteristics. The major outputs of the front-end analysis are summarized in Figure 1. This figure shows the seven major parts of the front-end analysis, associated with the major outputs. Each of these parts is summarized below.
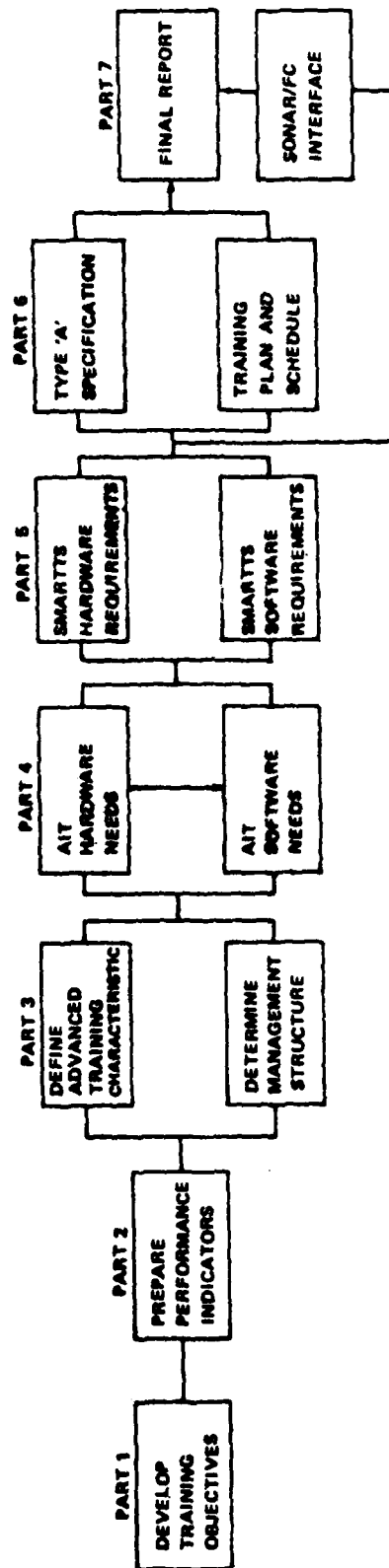
Figure 1. Major output of SMARTTS developmental effort

2.1.1 TACTICAL BEHAVIOR ANALYSIS (PART 1). An extensive behavioral data base relating to the tasks of individuals within the submarine combat team (i.e., fire control party and sonar party) and the team itself is resident at Eclectech Associates, Incorporated as a result of various analyses conducted pertaining to submarine officer tactics operations (e.g., Hammell and Mara, 1970; Hammell et al. 1971; Hammell et al. 1973). The behavioral analysis utilized the task, knowledge and skill information resident in this data base, updating it as necessary to cover the more recent weapon system developments (e.g., tasks specifically related to Tomahawk and Harpoon missiles). The major output from this analysis was the development of a comprehensive set of behavioral training objectives relating to members of the submarine fire control party.

It should be noted that the SMARTTS preprototype primarily addresses training of the fire control party, and does not specifically address the sonar party. However, since the fire control and sonar parties are closely integrated within the combat team from an operational standpoint, and often also during training exercises, the potential applicability of SMARTTS characteristics to the sonar party was also investigated. The sonar party requirements were investigated under Part 7 of the front-end analysis, separate from the major thrust which focused on the fire control party (Part 7 is summarized later).

The major accomplishments of Part 1 were:

a. Determined trainee entry characteristics for members of the submarine fire control party, as related to team training involving the SCST.

b. Identified terminal skill and knowledge requirements for the submarine fire control party, as related to tactical team training employing the SCST.

c. Determined U.S. Navy submarine missions, offensive roles, and operational tasks, and identified the preceived criticality of each.

d. Identified and integrated into the other accomplishments consideration for current and potential submarine tactical doctrine, including the characteristics of present and planned tactical hardware systems.

e. Delineated the current SCST training-related capabilities.

f. Developed a comprehensive set of submarine fire control party tactical training objectives for a specific application in SSN/SSBN refresher training type employment of the SCST.


2.1.2 PERFORMANCE CRITERIA, INDICATORS, AND STANDARDS (PART 2). The tasks under this part were directed toward the identification of candidate performance indicators for inclusion in the preprototype SMARTTS. Both objective (i.e., automatically calculated by the computer) and subjective (i.e., unable to be calculated by the computer; observed and estimated by the instructor) performance indicators were considered. Associated with the

performance indicators and considered in this grouping were tactical variables relevant to the performance of the fire control party (e.g., signal to noise ratio), and warranted for provision of feedback information during training. The accomplishments as follows:

a. Developed a set of comprehensive submarine tactical performance criteria specifically keyed to USN submarine missions, roles and tasks.

b. Developed and verified submarine tactical performance indicators suitable for use in the SCST environment on the basis of the identified performance criteria and current submarine tactical doctrine; relevant tactical variables were also identified.

c. Developed a plan of approach for the use of information generated by performance indicators and tactical variables during the SCST training process.

2.1.3 TRAINING STRUCTURE AND PROCESS DEVELOPMENT (PART 3). The tasks in this part continued the analysis begun during the two earlier parts and extended it to the instructor. The instructor task analysis yielded valuable information pertaining to required training device and system characteristics to support his functions. The results of these analyses were then fitted into a macro and micro training structure, with the former addressing intersite aspects and the latter addressing intrasite aspects. The accomplishments were:

a. Examined and developed requirements pertaining to the instructor interface within the training device/system; this was based on an instructor task analysis.

b. Examined and developed requirements pertaining to the trainee interface of the training device/system, primarily as controlled by the instructor (e.g., feedback information requirements).

c. Developed candidate training process functional characteristics to satisfy the instructor and trainee interface requirements.

d. Developed a macro structure training management process addressing training-related functions of the major naval activities as they impact the submarine tactics training system, and communication and coordination between these activities.

e. Developed a micro structure training process addressing the activities to be performed locally at each SCST facility; this is primarily concerned with the development of instructional materials and the conduct of the training process at each site.

2.1.4 AUTOMATIC INTERACTIVE TARGET MODEL (PART 4). A major characteristic identified by earlier investigations (Hammell et al., 1973), and receiving special consideration during this analysis was the automatic interactive target, which is a computer driven target that reacts in a realistic manner

to ownship actions and other factors in the environment. The automatic interactive target (AIT), in addition to issues of relevancy during the training process, required analysis regarding the feasibility of design and application. The major accomplishments of this part were as follows:

a. Established general tactical characteristics of known and expected threat targets appropriate for SCST training.

b. Correlated expert operational experience with the most recent source documentation to establish a framework for threat tactical decisionmaking appropriate to each main threat platform group.

c. Developed a complete set of tactical action-reaction sequence diagrams to cover known and expected tactical employment of a high priority threat submarine platform (Type II SSGN); this platform was selected as the initial AIT model.

d. Developed tactical maneuvering and tactical interaction response criteria most likely to be encountered from a high priority threat submarine platform (Type II SSGN).

e. Identified AIT hardware and software functions.


2.1.5 HARDWARE AND SOFTWARE CONSIDERATIONS (PART 5). Alternative hardware and software approaches were investigated with regard to accomplishing the functional characteristics identified in Part 3, and the AIT model identified in Part 4. The intention of these tasks was to generate information pertaining to alternative hardware/software approaches to the design of the SMARTTS preprototype, and the recommendation of a particular design approach. The accomplishments were as follows:

a. Summarized existing and projected SCST designs.

b. Summarized other selected automated submarine operational training systems and their hardware/software technology.

c. Developed a preprototype SMARTTS system design approach.

d. Identified alternative system configurations.

e. Conducted a system trade-off analysis.

f. Determined hardware and software functional requirements.


2.1.6 TYPE A SPECIFICATION (PART 6). The "Type A Specification", which identified the functional characteristics recommended for SMARTTS, was developed under this part. The accomplishments were:

a. Developed the "Type A Specification" identifying the SMARTTS TAT characteristics on a functional level.

b. Developed a training plan and schedule for implementation of the preprototype SMARTTS.

2.1.7 SCST SONAR TRAINING/INTEGRATION (PART 7). The applicability of the SMARTTS characteristics to sonar training was investigated under this part. The final report for the front-end analysis was also developed under this part. The accomplishments were:

a. Analysis of sonar operational team training requirements with regard to the joint operation mode of the SCST and the sonar trainer (e.g., 21B64).

b. Expanded the Type A Specification to include sonar operational team training considerations.

c. Identified site-specific functional requirements for the 21A41 SCST, which would employ the preprototype SMARTTS installation.

d. Development of a top-level system definition specification for the preprototype installation at the 21A41 SCST site.

e. Development of the front-end analysis final report (Hammell, Henry, Ewalt, Natter and Chidley, 1980).

The above discussion indicates the products developed during the front-end analysis, as well as provides an indication of the approach taken in that analysis. The final report of this analysis provides greater detail of the methodology and results. It also summarizes observations of SCST training at the various sites; provides substantial information regarding alternative training methodologies, instructor functions, guidance relevant to the setup and conduct of the training process (e.g., scenario design, postscenario briefing), operator and instructor training requirements and recommendations in support of the SMARTTS subsystem, and the design and application of the recommended SMARTTS characteristics.

2.2 CONTROL GROUP INVESTIGATION

The preprototype SMARTTS development and installation on the 21A41A SCST was a research and development effort to evaluate the training effectiveness resulting from the integration of TAT into an existing training device in an applied operational training setting. A necessary part of the SMARTTS effort, therefore, is the empirical evaluation of the change in the effectiveness of submarine officer tactics training resulting from the addition of SMARTTS. An experimental design was developed for the empirical investigation, to generate data pertaining to the effectiveness of tactics training prior to and following the installation of SMARTTS on the 21A41A SCST, and to yield statistically supportable results addressing the training effectiveness of specific SMARTTS TAT capabilities. The experimental design focused on a comparison of the training gain achieved during a standard tactics training course using the traditional 21A41 SCST, with the training gain achieved during the same course using the integrated SMARTTS/21A41A

SCST device. This comparison would demonstrate the change in training effectiveness due to the installation of SMARTTS.

Submarine tactical operations is a complex process involving a team of officers and enlisted personnel. The fire control party typically has 12 to 15 members, each of whom performs different functions, and interacts with different operational devices. The measurement of individual and overall team performance, therefore, is inherently complex and difficult. Although objective performance indicators are available, such as those developed and implemented under SMARTTS, they typically do not address the overall performance of the team. Rather, they address team and/or individual performance pertaining to a specific subset of tactical concerns (e.g., probability of counterdetection addresses one subset of concern during a tactical encounter). The various performance measures addressing different issues, which may change in conflict with each other as a function of ownship operations, are extremely useful from a training standpoint. Their purpose is to provide information regarding the relevant and often diverse issues. However, assessment of training effectiveness necessitates cohesive measures which summarize the team's performance. Also, many of the relevant aspects of tactical performance are not readily observable in computer data, but must be evaluated by a trained observer. Hence, a multifaceted evaluation tool was necessary to address (a) overall team performance, (b) different aspects pertaining to subsets of team and individual performance, and (c) objective and subjective evaluation data.

Several data collection and evaluation tools were developed with which to observe training and generate data pertaining to the level of tactical team performance. The tools focused on the collection of specific tactical parameter data, and observation by experienced submarine personnel of specific aspects of team performance (e.g., communication). The data collection tools and techniques were evaluated in a "pilot" evaluation, during which submarine teams were actually observed in training. The tools were subsequently modified on the basis of this preliminary evaluation.

2.2.1 DATA COLLECTION TOOL DEVELOPMENT. The data collection and evaluation tools were specifically developed for SSN 688 class fire control team members, 21A41 SCST instructor performance, and for use in the SMARTTS evaluation. The tools were developed to encompass refresher/postoverhaul, predeployment, and TRA-time trainer employment. They were prepared to discover a broad scope of fire control team performance factors including those of the fire control/sonar plotters, MK81 operators, fire control coordinator, and approach officer utilizing the MK117 fire control system. The evaluation tools were organized to be compatible with both the current 21A41 configuration and the future SMARTTS 21A41A preprototype installation. The evaluation tools also reflected the requirements of the submarine tactical doctrine and current 21A41 staff concepts of trainee performance and training difficulty. The data collection format and evaluation criteria were developed working in close liaison with the 21A41 SCST staff.

Information considered for inclusion in the data collection tools were:

a. Crew background and portion of tactical course that was applicable.

b. Applicable exercise training issues and overall objectives as identified by the instructor and/or crew commanding officer.

c. Applicable 21A41 SCST tactics course -- operational objective as identified by the instructor, squadron training officer and/or commanding officer.

d. Exercise difficulty level, number and identification of targets, mix of threat versus nonthreat targets.

e. Scenario initial setup and background conditions, geometry, environment, use of sensors, etc.

f. Target actions, maneuvers, and times of occurrence.

g. Ownship actions, maneuvers, and times of occurrence.

h. Weapon employment -- type, number, time of fire, initial settings, postfire changes and settings, torpedo run, and hit/miss.

i. Individual and team level performance to prescribed criteria.

The data collection effort used five data forms consisting of the following:

Part A:  Overall evaluation of team work.
Part B:  Instructional format, regarding the tasks of instruction.
Part C:  Fire control party individual training evaluation, addressing the performance of each operator.
Part D:  Summary of exercise sequence, evaluating team performance factors during each sequence of the exercise.
Part E:  Fire control party individual training evaluation, evaluating the improvement of performance over the course for each trainee.

2.2.2  DATA COLLECTION.  Data were collected over a 6-month period, observing and evaluating the training performance of teams on the 21A41 SCST in Norfolk, and the 21A37 SCST in New London.  The data collection was accomplished at these sites prior to initiation of extensive liaison between the 21A41 site personnel and the SMARTTS project team.  Since many of the relevant SMARTTS characteristics are manually implemented without a computer-based capability, it was believed that interaction between the SMARTTS team and site personnel would have a positive impact on the effectiveness of the training being conducted.  Since the control group data represent the traditional training effectiveness without SMARTTS, it was necessary to collect those data prior to the site having interaction with the SMARTTS project team.

2.2.3  PERFORMANCE EVALUATION.  The data collected from the three training groups (i.e., refresher/postoverhaul, TRA-time, and PCO training) will be

directly compared to comparable groups observed in training after the installation of SMARTTS. The observations to be made after the SMARTTS installation were planned to use the same forms and data collection procedures used to obtain the control group data. The planned comparisons address: (a) overall team performance, (b) team work improvement over exercise sequences, and (c) instructor performance. It should be noted, that information regarding the instructor's tasks and functioning is also a part of the data collection, since SMARTTS is aimed at assisting the instructor in performing his functions. The MK117 fire control system combat team will be evaluated in tactical areas including information generation, information use, sequencing actions, communications, coordination involving interpersonnel behaviors, and attitude.

Only the control group data have been collected at the current time. These data become meaningful only when compared with those collected during SMARTTS/21A41A SCST training. The post-SMARTTS training effectiveness data collection effort and the subsequent evaluation of the training effectiveness contribution made by SMARTTS is under consideration by the Navy. It is uncertain at this time whether this test and evaluation will occur, and if so to what extent.

The detailed information concerning the SMARTTS control group data collection effort is contained in the final report of that task (Ewalt, Hammell, Henry and Natter, 1981).

SECTION III

SMARTTS DESCRIPTION

SMARTTS is a preprototype strap-on unit to the 21A41 Submarine Combat System Trainer (SCST) at the Fleet ASW Training Center, Atlantic located in Norfolk, Virginia (note, the new trainer designation with SMARTTS is 21A41A). The SMARTTS preprototype is capable of either standalone operation, or operation integrated with the simulation subsystem of the 21A41 SCST in support of attack center training and classroom training. The 21A41A SCST, including the SMARTTS addition, addresses the training of combat teams of the SSN 688 class submarine, using the MK117 fire control system and AN/BQQ5 sonar. SMARTTS hardware consists of an instructor console located in the attack center to monitor and control various aspects of the problem, monitor aspects of trainee performance, and control information to be presented on two overhead CRT displays in the attack center. A similar instructor console is located in the adjacent classroom to control a large screen display. Both the classroom and attack center subsystems can be operated prior to, during, and following an attack center exercise. The intention of this design is to support a variety of tactics training needs across multiple courses and levels of trainees.

The essence of SMARTTS is its capability to collect and generate a variety of information pertinent to the tactical training problem, and to display various combinations of that information on the instructor console, the classroom large screen display and the attack center overhead monitors at appropriate times during the training process. Substantial su port capabilities are resident in the system to manipulate the information in various ways as required during the training process.

The preprototype SMARTTS does not incorporate all of the characteristics recommended in the "Type A Specification" of the front-end analysis. Rather, the preprototype unit includes those characteristics deemed to be essential to the SMARTTS concept of TAT, and which were feasible within budget and time constraints. Characteristics beyond those incorporated in the preprototype unit (e.g., instructor interface language) should be carefully considered in future developments. Section 5, Recommendations, provides a research and development plan identifying areas for further development of TAT following from the SMARTTS preprototype. Several of these are concepts put forth in the "Type A Specification", but not included in the preprototype unit.

A summary overview of the SMARTTS system is provided in the remainder of this section. This includes (a) a hardware overview identifying the major hardware components of SMARTTS, (b) a description of the SMARTTS characteristics, and (c) a brief summary description of the SMARTTS software.

## 3.1 SMARTTS HARDWARE

The essence of SMARTTS is in the training-related capabilities that are implemented via hardware, software, and training materials. The additional

hardware added to the 21A41 SCST to support SMARTTS was not substantial. In fact, the SMARTTS capabilities could be (i.e., and should be) integrated into training devices at the time of initial concept design; and followed through their developmental process. Many of these SMARTTS-type capabilities have their roots in processes that are already carried-on inside typical computer-based training devices. If incorporated in the initial design, the SMARTTS unit would comprise the instructional subsystem, simply interfaced with the simulation subsystem.

The SMARTTS hardware is divided into three major groups, (a) the attack center subsystem, (b) the classroom subsystem, and (c) the model deck subsystem. The model deck subsystem consists of the host computer (VAX 11/780) for SMARTTS, with appropriate interfaces to the MK117 fire control system, the 21A41A SCST simulation computer, and other necessary devices. Virtually all of the SMARTTS data collection and processing is conducted by the host computer. The major components of SMARTTS hardware, integrated with the existing 21A41A SCST hardware, are illustrated on the component block diagram of Figure 2. They are:

a. VAX 11/780 SMARTTS host computer (left of center in diagram). This host computer is connected to all of the other SMARTTS components, and functions to collect data, process the data, and drive the various information displays.

b. Interface to the main simulation computer group (MSCG, UYK-7) (center of Figure 2). This is the two-way interface between the SMARTTS host computer and the 21A41A SCST simulation computer (i.e., a computer that simulates targets, the environment, etc.).

c. Interface between the SMARTTS host computer and the MK117 fire control system computer (UYK-7) (upper right-hand of Figure 2). This is the interface to the operational fire control system computer. Information is collected from the MK117 regarding various aspects of the ongoing tactical problem.

d. Instructor Remote Console (IRC) (near upper center of Figure 2). The instructor remote console is the instructor's console located in the attack center. The IRC has two display surfaces (see Figure 3): the upper surface is a color graphic CRT, and the lower surface is a touch sensitive plasma display. The upper CRT is used to present a variety of information to the instructor in both graphical and alphanumeric formats. The information display formats discussed later in this section (3.2.4) provide examples of information presented on the upper display. The lower plasma display is used as the primary instructor entry device. It displays an alphanumeric listing of the appropriate available input commands at any point in time (see Figure 4). It has an XY touch sensitive grid pattern that permits the instructor to point to his choice of input commands, and thus enter commands into the system. The lower plasma display also presents some status information. The IRC can be used to investigate various scenarios and their pertinent parameters prior to running them in real-time on the trainer, to setup an exercise on the trainer, to control various activities during a training exercise (e.g., maneuver targets), to monitor a wide variety of performance indicators and tactical information during the

SHADED AREA: EXISTING 21A41 SCST EQUIPMENT

NON-SHADED AREA: SMARTTS EQUIPMENT
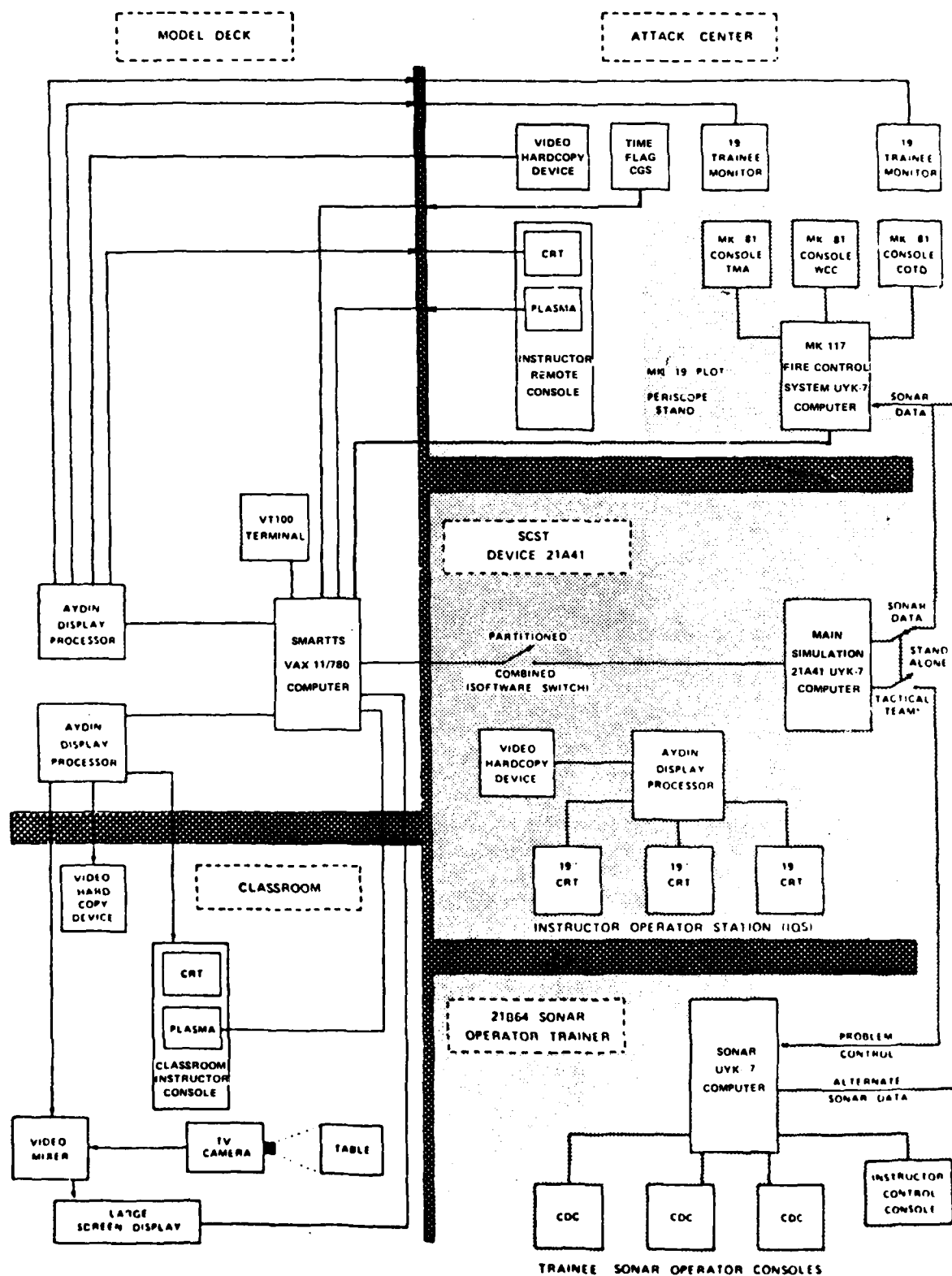
Figure 2. SMARTTS/SCST equipment diagram

# SMARTTS
# INSTRUCTOR CONSOLE

● PROBLEM STATUS

● INFORMATION
PRESENTATION
ATTACK CENTER
CLASSROOM

● LONG TERM DATA

● CUES & ALERTS

● ENTER OBSERVATIONS

● EXERCISE DEVELOPMENT
FAST—TIME MODELS

● EXERCISE SELECTION
& SET—UP

● PROBLEM CONTROLS
OWN SHIP TARGETS
SIMULATOR

● PERFORMANCE MONITORING
(DISPLAYS)
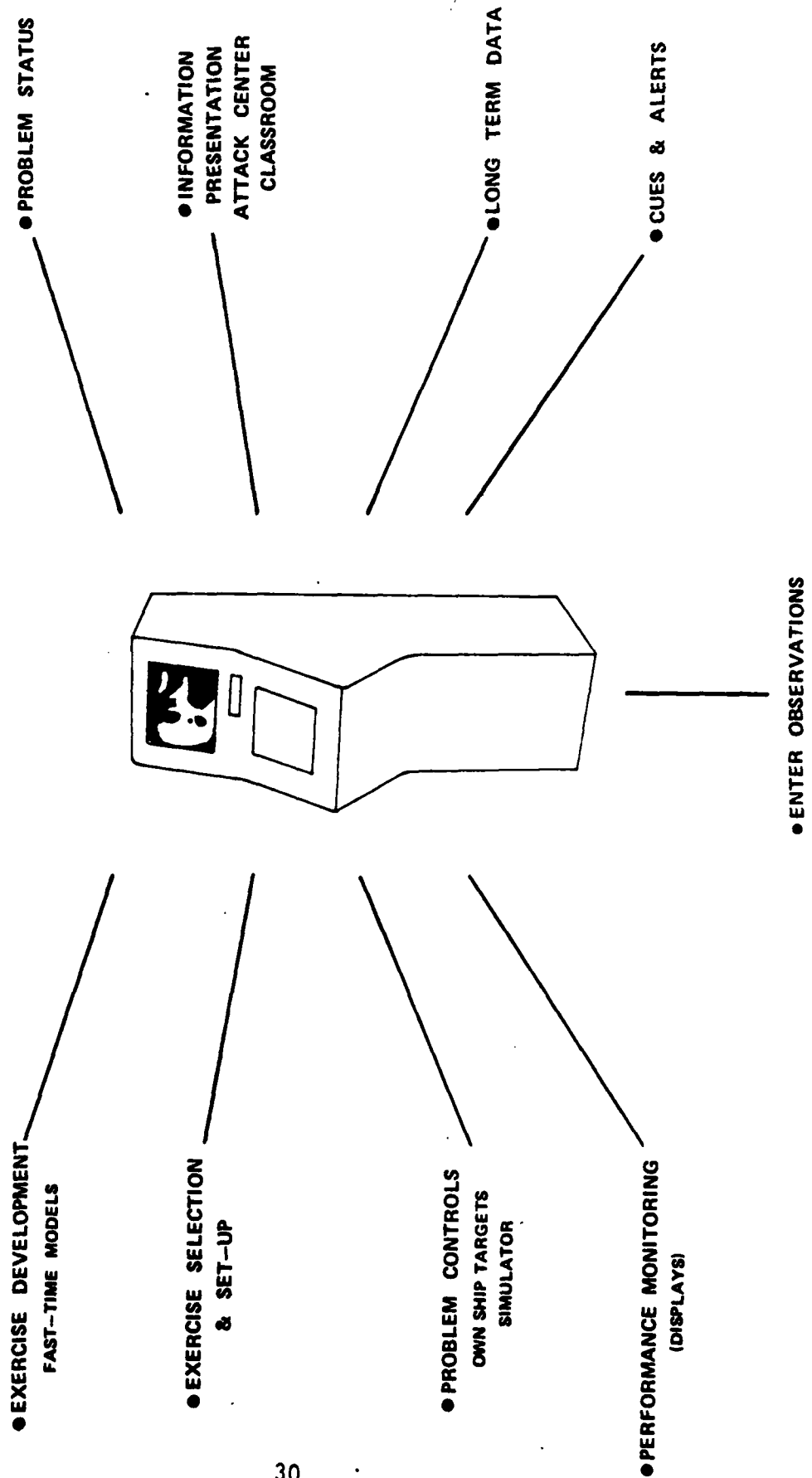
Figure 3.  IRC display surface

30

Figure 4. Display of an alphanumeric listing of the appropriate available input commands

training exercise, and to select and control information for presentation on the overhead displays in the attack center, either prior to, during or following the actual real-time exercise in the attack center.

e. The two overhead displays in the attack center are noted as trainee monitors, two blocks in the upper right of Figure 2. These are color graphic 19 inch CRT monitors hanging from the overhead.

f. Six time flag switches are available in the attack center and moveable to various operator positions (upper right in Figure 2). Trainees can press the time flag switch at any point during an exercise, with subsequent recording of the time at which it was pushed for reference purposes during exercise playback.

g. The Classroom Instructor Console (CRC) (lower left of Figure 2). It is identical to the IRC, but located in the classroom. The information available on the CRC is identical to that available on the IRC, as are the controls and input sequences. The major differences between the IRC and the CRC center around the capability on the IRC to control the attack center simulation exercise in real-time. The CRC can also control exercises, but only during their running in the classroom (e.g., during prebriefings or postbriefings). The primary purpose of the CRC is to control and manipulate information on the large screen classroom display.

h. The large screen classroom display is shown in the lower left-hand corner of Figure 2. It is a large screen raster display driven by an Aquastar projector. In addition to the computer generated information that can be presented, a TV generated image of the manual plots, and other status displays from the 21A41 SCST MSCG can be presented on the large screen display.

i. Video camera (lower left in Figure 2). A TV camera stand and table is located in the classroom. The manual plots can be laid on the table, with their video image picked up by the camera and used to generate the plot image on the large screen display. A computer generated plot overlay can be superpositioned on the manual plot presentation of the large screen display for comparative purposes.

j. A hard copy unit is available, as part of SMARTTS, in the classroom to permit the generation of a hard copy representation of the large screen display image.

The remaining hardware components in Figure 2 are SMARTTS interface equipment and existing attack center, sonar, and other 21A41 equipment.

The locations of the SMARTTS attack center components are considered critical to their effective utilization. Figure 5 shows the locations of the two overhead displays and the IRC within the attack center. The overhead displays are positioned so that at least one display is readily viewable by all members of the fire control party. Several potentially effective locations were identified for the IRC. IRC cable connections are, therefore, provided at three different locations within the attack center facilitating its relocation in a short period of time. The initial
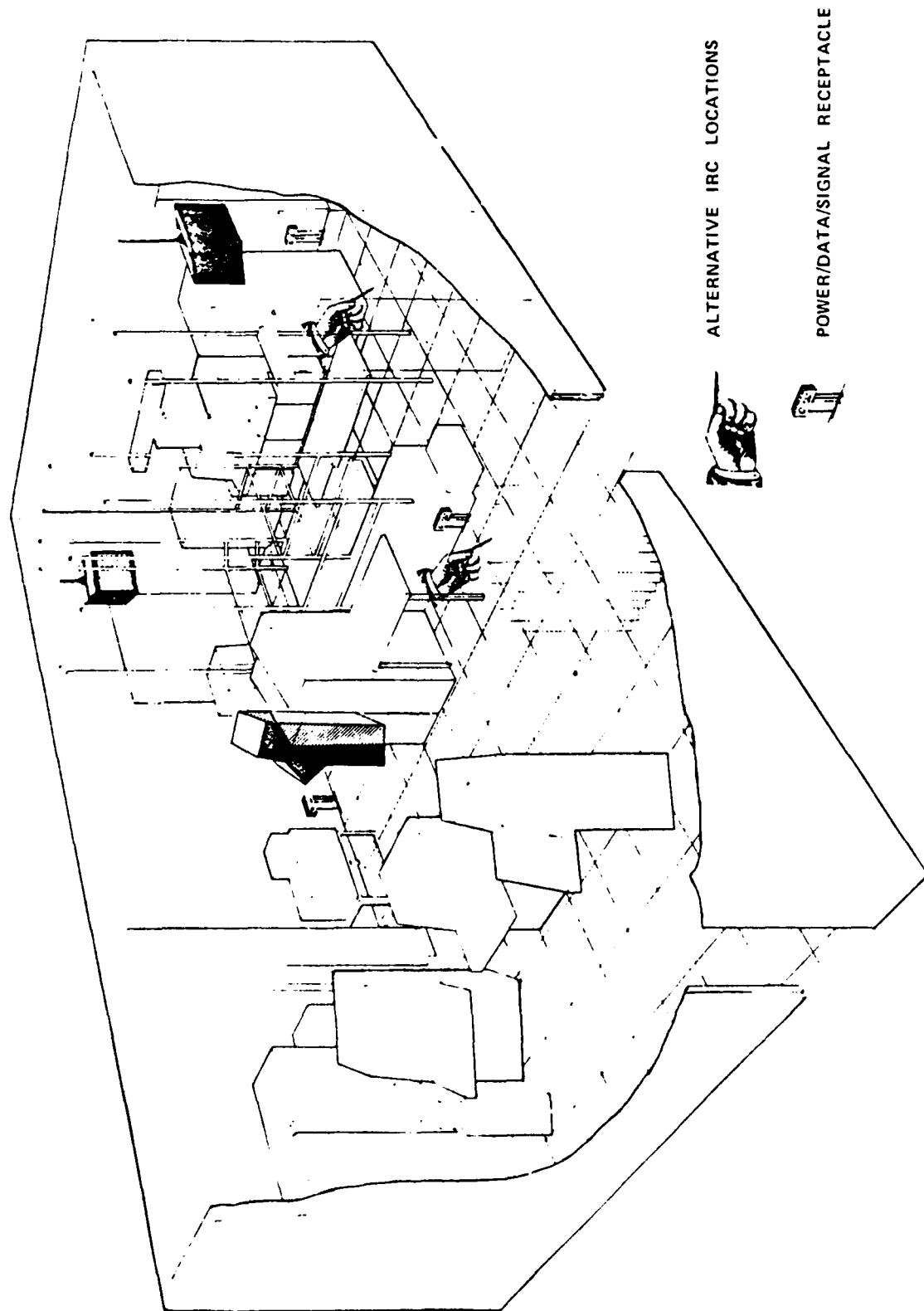
Figure 5. Attack center general arrangement

ALTERNATIVE IRC LOCATIONS

POWER/DATA/SIGNAL RECEPTACLE

installation of the IRC is at the location shown in Figure 5, which is believed to be the best all around choice.

The CRC is positioned in the classroom to one side of the large screen display. This positioning enables the instructor to be in front of the students, and to be able to manipulate the CRC while viewing both the students and the large screen display.

The capabilities of the major components are further addressed below regarding the description of the SMARTTS characteristics.

## 3.2 SMARTTS CHARACTERISTICS

The SMARTTS preprototype was designed to be the training subsystem of the 21A41 SCST training device. As such, it provides characteristics in support of a wide range of instructor functions, provides characteristics to assist the instructor in achieving an effective trainee interface within the training process, and provides rudimentary characteristics to assist in training system management. These characteristics support the four major functions of the training process: (a) exercise development, (b) monitor and control of the real-time training exercise scenario, (c) instructing the student (e.g., briefing), and (d) training system management (Appendix A contains a summary explanation of these functions and the SMARTTS characteristics supporting each, taken from Hammell, 1982). Each major SMARTTS characteristic is summarized below.

3.2.1 SMARTTS TRAINING. SMARTTS characteristics support both classroom and attack center training. They can be used simultaneously in both locations, supporting the four major training process functions. Furthermore, they are intended to be used to initiate the training process prior to conducting the real-time training exercise scenario in the attack center, to support the conduct of that exercise scenario in the attack center, and to follow-up after the exercise scenario is completed. The variety of SMARTTS characteristics to support these vary considerably, and permit the instructor substantial flexibility in tailoring the training methods to the various pertinent considerations.

3.2.1.1 Exercise Preview. Exercise preview characteristics enables the running of an exercise in the classroom or in the attack center (i.e., via the IRC and overhead displays) without the use of the main simulation/fire control system. Appropriate ownship, target and environmental models are present in the SMARTTS software to simulate the exercise scenario without the use of the main simulator. These preview characteristics has simulation models for the following:

a. Ownship actions

b. Target actions

c. Ownship noise condition as a function of aspect and speed

d. Target noise level as a function of specification and speed

e. Sonar reception

f. Environment

g. Target motion analysis computations, in terms of a system solution simulation sensitive to ownship maneuvers, signal to noise ratio, target maneuvers, etc.

h. The tactical variables and performance indicators are also calculated during exercise preview.

The preview characteristics are useful for the instructor to develop exercises, in that it enables the running of each exercise at fast-time in an off-line mode. These characteristics are also useful for previewing exercises shortly prior to running them on the simulator. The greatest use of the preview characteristics perhaps, is during a classroom prebriefing to the trainees. Prebriefing would logically precede the actual conduct of the exercise in real-time on the training device.

During the prebriefing the instructor could demonstrate several problems, investigating acceptable and unacceptable sets of tactical actions, or focusing on relevant PIs and tactical variables. The preview characteristics enable this type of investigative analysis to occur for any tactical problem. They can also be used to investigate various problems during the debriefing session, in a similar manner, prior to the subsequent scenario in the attack center.

3.2.1.2 <u>Exercise Run</u>. Many of the SMARTTS characteristics have been designed to support the instructor during the conduct of the real-time exercise in the attack center. These capabilities center around the IRC which presents the variety of information needed by the instructor to monitor and control the exercise, in a location immediately adjacent to the fire control party to facilitate his interaction with the trainees. The input commands available on the IRC, via the user-friendly touch sensitive plasma panel, enable the instructor to control the trainer and scenario, and to manipulate relevant information and displays. SMARTTS moves the traditional information and control capabilities to an effective and convenient location for the instructor; generates and provides additional necessary information to assist the instructor; and greatly extends the instructor's capabilities to control the exercise and instruct the trainee.

The two overhead displays in the attack center can provide status information for viewing by the trainees during the real-time exercise, if so desired by the instructor. The information to be presented on these displays is completely under the instructor's control via the IRC.

3.2.1.3 _Freeze_. SMARTTS has the capability to freeze time and all SMARTTS VAX and MSCG computations at any point during a real-time exercise in the attack center. Plans have been underway to implement an automatic freeze of the MK117 fire control system; this capability is not currently implemented. Freeze enables the instructor to pause during a problem and to provide necessary instruction before proceeding further. For example, after ownship has been proceeding on a particular approach sequence, the instructor may want to freeze the problem and discuss other alternative actions (e.g., their pros and cons) and then continue on with the real-time scenario. Another instance in which the instructor may wish to use freeze is when the student combat team has made a fundamental mistake early in the scenario which would inhibit achieving the objectives the instructor is focusing on; the instructor might freeze the problem to point out the mistake and get the team back on the right track prior to proceeding into the heart of the problem.

SMARTTS supports the instructional process during the freeze by enabling the generation of information and its presentation on the overhead displays in the attack center, under the control of the instructor via the IRC. The overhead displays can provide information to the team to assist the instructor in getting his points across.

3.2.1.4 _Exercise Playback_. A substantial amount of data is collected from the training device while an exercise scenario is being run in real-time. These data are collected from the simulation computer (e.g., target sonar related data) and from the MK117 fire control system (e.g., _system solution_ data), as well as other SMARTTS-generated data (e.g., subjective observations). The collected data can be rerun during exercise playback in real-time, or in accelerated time up to 16x real-time. Playback can be accomplished in either the attack center using the overhead displays controlled by the instructor's remote console, or in the classroom using the large screen display controlled by the classroom instructor's console. All the SMARTTS display formats are available for viewing during playback.

Typically, the instructor would present the problem on a version of the approach geoplot display format which provides the geographic layout and history tracks for ownship and all other contacts. Additional display formats would be used as appropriate with regard to the particular training objectives, problem scenario, and so on. The alternative tactics characteristics discussed below are also available during playback, such that the instructor can stop the playback at any point in time and investigate alternative ownship and target actions from that point on.

3.2.1.5 _SMARTTS Training Process_. The playback characteristics, supported by the display formats and other SMARTTS features, are essential to an effective training process. Instructional feedback is generally provided in the playback mode of SMARTTS operation during problem scenario debrief, also utilizing the other SMARTTS capabilities. The ideal training exercise conducted with the 21A41A/SMARTTS would generally be conducted as follows:

a. A prebriefing session would be conducted in the classroom using the SMARTTS preview characteristics to investigate relevant tactical issues and several problem scenarios in fast-time; various display formats and SMARTTS characteristics would be drawn upon to dissect the scenarios and achieve technical understanding of the tactical issues involved. This would prepare the trainees for the subsequent real-time exercise scenario to be conducted in the attack center.

b. A real-time exercise scenario would be conducted in the attack center during which the trainees would put into practice the principles, skills, and knowledge they gained from the prebriefing session. This would typically be done at a real-time pace. The control and monitoring characteristics of SMARTTS would be used by the instructor, along with other characteristics as appropriate (e.g, overhead displays in the attack center during a freeze).

c. A debriefing session in the classroom would immediately follow completion of the attack center exercise scenario. The SMARTTS playback characteristics would be used to provide various forms of feedback to the trainees. Typically, this would start with a fast-time replay of the entire exercise scenario, using an approach geoplot display format along with several other display formats, presented on the large screen display in the classroom. The instructor would then focus on certain important segments of the exercise to investigate aspects of trainee performance in greater detail (i.e., both good and poor performance). The intention would be to provide specific feedback to the trainees regarding their performance and the factors affecting it, and to explore alternative actions open to them and their resulting consequences. SMARTTS assists the disecting of the exercise by retrieval of pertinent information that occurred throughout the exercise as it was run in real-time in the attack center.

d. The debrief would move from a focus on the previously run attack center exercise scenario to focus on subsequent tactical issues of interest. The subsequent issues could be, for example, offshoots of the tactical exercise to better clarify relationships between tactical variables (e.g., PCD and ownship speed) to dig deeper into particular aspects of the training objectives currently being addressed, or to move on to subsequent training objectives. This next part of the debrief would change into a classroom discussion, and eventually into a prebrief for the next exercise scenario to be run in the attack center. The various SMARTTS characteristics, such as alternative tactics and exercise preview, would be used during this phase of the training process. Eventually this phase would become step 1 noted above in preparation for the next exercise scenario.

It should be evident from the above, that the SMARTTS characteristics support both classroom and attack center training. Furthermore, they are intended to be used to initiate the training process prior to conduct of the real-time exercise scenario in the attack center, to support the conduct of that exercise scenario in the attack center, and to follow-up after the exercise scenario has been completed. The variety of SMARTTS characteristics to support these vary considerably, and permit the instructor substantial flexibility in tailoring the training methods to the various pertinent considerations (e.g., training objectives, trainee input

characteristics, etc.). The particular SMARTTS characteristics to be used will, of course, depend upon these factors.

3.2.2 PERFORMANCE INDICATORS. Performance indicators (PI) are critically important to the effectiveness of the training process. The PIs, together with other relevant tactical information, comprise the main body of information relevant to specific aspects of individual and team tactical performance. As such, they constitute the trainee guidance and feedback information critical during the training process. The performance indicators are generated by SMARTTS based on information collected from the MK117 fire control system, the main simulation computer, and the instructor. Each performance indicator addresses a specific tactical aspect of the problem relevant to various training objectives. The PIs have been developed in two groups: (a) objective PIs which are automatically generated by the computer, and (b) subjective PIs which are manually entered into the computer by the instructor, based on his observations. The algorithms used to calculate the objective PIs use tactical data and other parameters as inputs (e.g., rate of change of bearing, time and distance to the target, target angle on the bow, target sonar performance, etc.) which are normally generated throughout any trainer exercise. Many of the objective PIs are calculated once per minute and recorded, enabling their display at various times during or following the exercise in graphical format. All objective PI values are available for presentation at or near the time of occurrence of their measured events during the tactical exercise, when selected by the instructor (i.e., presented on the instructor consoles or overhead and large screen displays). Time history plot displays of PIs are also available, showing their instantaneous value as well as a plot of their previous values during the scenario (see information displays below). The objective PIs are:

    a. Probability of counterdetection

    b. TMA system solution - course accuracy

    c. TMA system solution - range accuracy

    d. TMA system solution - speed accuracy

    e. TMA system solution - depth accuracy

    f. Approach position - track angle

    g. Closing rate - across line of sight

    h. Closing rate - in line of sight

    i. Time to station - (i.e., time to approach position)

    j. Torpedo run

    k. Periscope exposure time

    l. Kalman automatic sequential target motion analysis (KAST) reset times

The subjective PIs involve instructor observations of particular factors that occur during the exercise, such as the trainee team's minimum/maximum values for the initial target motion analysis (TMA) range estimate, or the overall effectiveness of fire control team communication. These are relevant PIs that cannot be readily calculated by automated means, but are of vital importance to the training objectives. The subjective PI values are determined by the instructor and entered into the SMARTTS computer at the IRC, and subsequently stored for later retrieval. Occasionally, a cue or an alert is provided to the instructor via the IRC to indicate a particular occurrence (e.g., PCD exceeding a preset value) after which the instructor may wish to observe certain aspects of performance and enter a subjective PI. The instructor's command indicating his desire to enter a subjective PI causes automatic selection of the appropriate data entry tableau on the plasma entry device. This facilitates instructor entry and recording of subjective PI values. The subjective PIs can be displayed for feedback purposes in a manner similar to that for the objective PIs, although they usually represent discrete points when looked at over time, rather than a smooth history track. The set of subjective PIs provided on the preprototype SMARTTS are:

a.  TMA initial range estimate, minimum and maximum.

b.  Recognition of target maneuvers, including time to detect the maneuver and the accuracy of evaluation.

c.  Periscope angle on the bow recognition.

d.  Periscope safety sweep procedure.

e.  Periscope search technique.

f.  Plot coordinator effectiveness.

g.  Fire control coordinator effectiveness.

h.  Fire control party interaction, including intraparty communication and interparty communication (i.e., between fire control party and other teams such as the sonar party).

The flexibility of the SMARTTS preprototype software design to enable evolution of system characteristics was given high priority. It is the intention that the specific characteristics of SMARTTS (e.g., performance indicators, display formats) can be easily modified to keep pace with the changing training objectives, tactical doctrine, training methods, and so on. Hence, the above list of objective and subjective PIs is not intended to represent the comprehensive list that should be used in submarine tactics training. Rather, it represents the first-cut at a set of acceptable PIs. It is fully expected that these PIs will be improved as a result of their use in training, and that additional PIs will be developed and implemented into the SMARTTS preprototype.

3.2.3 TACTICAL VARIABLES. The PIs summarized above represent specific indicators of tactical performance for individuals and for the team. They are typically used to provide feedback to the trainees immediately following a scenario, as well as to investigate alternative tactical actions prior to and following a scenario, contrasting the results in performance trade-offs between the various PIs. Several tactical variables (i.e., parameters normally occurring in the tactical encounter) are also critically important information sources to be used during preproblem and postproblem briefings. The tactical variables are based on the observed values of specific parameters as they occur during the exercise. The tactical variables are recorded in a manner similar to that of the objective PIs, and likewise available for display. That is, all tactical variables are available for presentation on the displays during tactical exercises under instructor control, and in accordance with the TAT characteristics involved. They can be presented on the IRC and the CRC, as well as the overhead displays in the attack center and the large screen display in the classroom. The tactical variables recorded by the preprototype SMARTTS are:

a. Ownship course

b. Ownship speed

c. Ownship depth

d. Target course

e. Target speed

f. Target depth

g. Target lead/lag angle

h. Target angle on the bow

i. Target true bearing

j. Target bearing rate

k. Target range

l. Target range rate

m. Target signal to noise ratio for assigned trackers

n. Target speed across the line-of-sight

3.2.4 INFORMATION DISPLAYS. Much of the work performed by SMARTTS is the collection of data from various sources, transformation of that data into meaningful tactical variables, performance indicators, and other forms, and presentation of relevant information on displays to the instructor and trainees. The various forms of information presented to the instructor directly support his functions of exercise development, monitoring and

control of training on the device, and control of information presentation to the trainees. The information presented to the instructor in addition to the performance indicators and tactical variables, consists of the ownship, target, and environmental parameters essential to exercise setup and control. The information presented to the trainees, on either the overhead displays in the attack center or the large screen display in the classroom, is primarily used to disect and investigate particular aspects of tactical problems, to provide status information concerning the particular exercise and scenario run on the training device, and to provide feedback information concerning the myriad of details regarding tactical performance during the scenario. The information presented to the trainees generally consists of the performance indicators and tactical variables. The SMARTTS information display characteristics, for both the instructor and trainees, are intended for use during prebriefing sessions prior to conduct of the exercise scenario in the attack center; during the conduct of the exercise scenario in the attack center; and immediately following completion of the exercise scenario. In addition, exercise development display characteristics are available to the instructor in an off-line context. It should be noted that a variety of processing capabilities has been incorporated into SMARTTS to manipulate information for display. These characteristics include, for example, ownship, target, and environmental models to support classroom investigations. Several of the major processing characteristics are summarized later in this section.

The information display characteristics are summarized below in terms of (a) the display formats, and (b) their intended use during the training process. The majority of display formats available on SMARTTS are designed to serve both the instructor and the trainees, during the various phases of the training process (e.g., classroom briefing, exercise scenario monitoring in the attack center). The information display formats are designed for both general and specific purposes, with the former useful in a variety of training-related applications, and the latter tailored to specific training objectives and/or tactical exercises.

The available SMARTTS display formats have two general purposes. One is to provide status information regarding various aspects of the tactical problem (e.g., geographic picture of ownship, target, and other vessels in the area; system solution accuracy at a particular point in time). The other is to provide performance-related feedback to the trainees regarding their actual actions during a particular scenario, or regarding alternative sets of actions available in various tactical scenarios. Often, the same display formats are used for both of these purposes. Hence, the summary provided herein does not distinguish the purpose for each display format. Furthermore, some display formats are intended for information to be provided to individual trainees, while others are intended for information to be provided to the complete team, while still others provide information for the instructor and instructional staff. Finally, many of the display formats are modularly constructed such that a particular format may be composed of several blocks, for each of which several alternatives are available. Hence, for example, geographical plot can be presented along up with associated performance indicator summaries; alternatively, that same geographic plot can be displayed along with a line-of-sight diagram from ownship to the target. Various combinations of the display blocks are

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available to be presented on a particular display format at any point in time.

The summary presented below is not intended to be comprehensive with regard to all of the display formats and combinations available on SMARTTS. Rather, it presents a representative overview of those that are available.

a. Geoplot Display -- This format (Figure 6) provides a geographical plot of ownship, the target and other contacts, weapons, and their history tracks. Several characteristics options are available for configuring this particular display format, such as the range scale for the geographic area (e.g., a 32 nautical mile scale is in the Figure 6 example). Immediately to the right of the geographical plot is an area available for display of associated information. In the Figure 6 example, six tactical variables presenting current status information are being displayed. This area could also be used for displaying up to three sets of performance indicators (selectable by the instructor). Figure 7 shows a geographical plot with an associated line-of-sight diagram, showing the relationship between ownship and the target. The line-of-sight diagram is a plot often constructed and used by the submarine fire control party during a tactical engagement. Its use associated with the geographical plot on this particular display format is to provide status information to the instructor during a particular exercise on the training device. Additionally, this display format (approach geoplot and line-of-sight) could also be used to provide feedback to the trainees during a freeze in the exercise, or during a postproblem feedback session in the classroom. When used to monitor the status of an ongoing problem, this display updates all parameters in real-time. When used to provide postproblem feedback, the scenario can be replayed at rates ranging from real-time to 16x real-time, with the display updating accordingly. This display format is also extremely useful during exercise development when the instructor is concerned with the interactions between the various platforms, tactical variables generated, and so on. Please note that a line of alphanumeric information can be presented at the very bottom of the display in Figures 6 and 7. This area is reserved for presenting cues to the instructor during the ongoing problem (e.g., alerts regarding target actions, performance indicators exceeding a preset threshold level, and so on).

b. Target Status -- This display format (Figure 8) provides several types of information relating to target status. The block of information on the left side of the display presents the target status in terms of system versus actual target motion analysis solution information for seven relevant tactical variables. This information allows the instructor to view a summary of target tactical actions, and enables him to monitor the difference between the actual target parameters and the solution achieved by the fire control party during the scenario. Several different blocks of information are available to present on the right side of this display format. The two blocks in Figure 8 address the performance indicator probability of counterdetection, the received sonar signal to noise ratio, and several ownship parameters (e.g., ownship course). The lower part of this status display, which is blank in Figure 8, could present information relevant to actions by the automatic interactive target (AIT) when an AIT is designated and turned on (refer to Section 3.2.9 for a description of the

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Figure 6. Graphic display format, with a block of status information.

CT
DMHT
HUT

380°
14.5KT
400FT

RH
9644
YD

DRH
0724
YD/MN

BYO
2

DBY
R
0/MN

TGT STATUS
TIME:01:54:40

| SOL | SYS | ACT |
|-----|-----|-----|

| CO ° | 130 |
| DMHO KT | 15.8 |
| HUO FT | 150 |

AI1). This display format would typically be used during the conduct of a scenario on the training device to monitor the system solution status and certain other tactical variables. Of course, it could also be used for off-line exercise construction, classroom monitoring and classroom briefing.

c. Time Function -- This display (Figure 9) plots a selected PI or tactical variable on the vertical axis, versus problem time on the horizontal axis. A combined total of up to three PIs and tactical variables can be displayed simultaneously on this display format. Each of the three curves is presented in a different color. The time function display format is used primarily to provide feedback information to the trainees subsequent to completing an exercise scenario in the attack center. This format is also very useful during preexercise briefings. A vertical cursor, which is positioned near time 0120 in Figure 9, can be manually positioned to any time in the exercise, or allowed to automatically follow the current exercise time. The value of each of the three displayed parameters at the time indicated by the vertical cursor is presented on the display in a digital readout form to the left of the vertical axis. The time cursor is placed at 0114 minutes in the example of Figure 9, with the selected parameter (TSP) value reading 999. If this cursor were moved to different times the corresponding values would be readout.

d. Trigraph -- The trigraph display places three time function plots on a single display surface (Figure 10). One to three PIs or tactical variables can be displayed on each of the three plots on the trigraph. Figure 10 shows a single parameter graphed on each of the plots. The vertical cursor, which can be manually or automatically positioned, is provided on the trigraph in a manner similar to that for the time function display (see above description). As shown in the Figure 10 example, the vertical cursor is positioned at time 0009, with three corresponding values displayed for the three parameters plotted. It should be noted, that a group of up to three PIs and tactical variables can be allocated to each of three data blocks for a total of nine parameters simultaneously displayed. When selecting parameters for certain displays such as the trigraph, the instructor can select the specific PIs or tactical variables he wishes to present, or he could select a particular data block or blocks he wishes to present. In the latter case, the PIs previously designated as comprising the three available data blocks would be automatically presented on the display (i.e., three PIs are automatically designated in each of three blocks as part of each exercise, or manually designated at any time by the instructor). Hence, for example, if three parameters were assigned to each data block, and the instructor selected three data blocks for presentation on the trigraph, nine parameters would be simultaneously displayed. This feature enables the instructor to rapidly select the often used PIs and tactical variables as groups without having to manually request each parameter.

e. Parametric Plot -- The parametric plot display presents a two axis graphical presentation of the relative values of two time continuous PIs or tactical variables on the same graph. One parameter is plotted on the Y axis while the second parameter is plotted on the X axis. The plot is similar to that of the time function graph, with the exception that the horizontal axis parameter is selectable rather than fixed as problem time.

The above display format examples are representative of those currently available in SMARTTS. SMARTTS contains additional display formats, as well as a variety of characteristics associated with all displays. As noted earlier, most of the display formats available under SMARTTS have multiple uses, including uses by the instructor for monitoring and exercise development, and for briefing and feedback information to the trainees. Usually, the specific display characteristics (e.g., PI's) are tailored to the particular purposes of the training exercise. The trigraph display, for example, is often used as a means of providing detailed feedback to the trainees following completion of an exercise/scenario on the training device. When used for this purpose relevant PIs and tactical variables are displayed as a function of time to illustrate (a) details of the tactical problem as it developed, and (b) relationships between the different tactical variables and PIs (e.g., relationship between probability of counterdetection and ownship speed). The trainees are able to see how a change in ownship speed affected a change in probability of counterdetection, for example, since both occurred at approximately the same time with the former being a function of the latter. The trigraph display is also useful by the instructor to monitor aspects of the problem as it is developing in real-time in the attack center. When the trigraph is used in this manner, the vertical time cursor is usually locked to the current time and updates the digital readouts in real-time as the problem progresses. The cursor, therefore, provides the instructor with a digital readout of the current value of up to nine different performance indicators and tactical variables at once, and also allows him to view a historical plot of their value from the onset of the exercise, or from any particular point in the exercise. These plots enable the instructor to observe trends in performance, such as a steadily increasing probability of counterdetection over time. Both the instantaneous and time history data are valuable to the instructor to interpret the evolving tactical situation and the trainees' activities, and hence to direct the problem or provide feedback (i.e., either immediate or postproblem delayed) regarding specific aspects of the problem and trainee performance. Several additional display formats are discussed later with regard to particular SMARTTS characteristics.

The SMARTTS software component that implements the displays was flexibly designed to permit modification of the display formats. A major intention of the SMARTTS design is to enable the system to evolve as the tactical and training needs and methods change. Hence, display formats are intended to be developed and implemented with regard to particular training objectives; the software is designed to encourage this type of modification.

3.2.5 ALTERNATIVE TACTICS. Learning by example has been traditionally accepted as an effective training methodology. Witness the extensive use of examples during lectures and homework problems. The alternative tactics feature of SMARTTS provides a computer-based capability to rapidly generate and investigate example problems. Prior to a real-time exercise on the training device the instructor may wish to explore particular concepts in the classroom (e.g., various barrier patrol patterns to intercept a transiting submarine) by illustrating the impact of ownship or target alternative actions on the performance indicators and tactical variables of

interest. This would provide the trainees with an understanding of the trade-offs associated with the various alternative actions available to them.

SMARTTS can generate several alternative sets of actions for a particular problem (i.e., both ownship and target alternative actions), generate the associated performance indicators and tactical variables, present the relevant information summaries on several display formats, and enable the instructor to draw comparisons between the various alternatives with regard to the objective PI and tactical variable developments and outcomes. Similarly, during a postscenario feedback session in the classroom the instructor may wish to illustrate alternative sets of actions for the particular problem encountered during the real-time scenario in the attack center. For example, after a 2-hour exercise during which ownship was on barrier patrol and encountered a transiting enemy submarine, took appropriate action to approach and attack, and eventually completed the scenario, the instructor may wish to illustrate the effectiveness of other sets of tactical actions for that particular problem. These alternative, sets of actions may be equally effective, less effective, or more effective. Also, it is often very difficult, if not impossible, to determine the "best" set of tactical actions since many interacting and often conflicting changing the factors are involved. From a training standpoint it is often more important that the trainees understand the various trade-offs involved with the particular actions they took in comparison with other available actions, rather than to be told that a particular set is the best. To adequately explore these trade-offs and alternatives, the use of examples providing objective PI and tactical variable information regarding each in a comparative format is extremely useful. The knowledge gained from this type of activity constitutes learning.

The alternative tactics characteristics is also useful by the instructor during the exercise development process. During the design and validation of exercise scenarios it is often necessary for the instructor to explore alternative sets of target and ownship actions to arrive at the final design. The alternative tactics characteristics provide a convenient means of setting up and evaluating these alternatives.

The alternative tactics characteristics include:

a. Up to five future ownship legs can be projected (i.e., each leg constitutes a segment of a scenario when ownship is on a constant course and at a constant speed).

b. Up to three target legs can be projected. The computer automatically projects ownship and target tracks in fast-time in accordance with the entered information.

c. Several tactical variables are calculated through the projected target and ownship maneuvers (e.g., bearing, bearing rate, range).

d. Several objective performance indicators are calculated through the target and ownship maneuver legs (e.g., target motion analysis solution accuracy, such as range; probability of counterdetection).

e.  The targets for which no alternative actions are entered are automatically projected at their current course and speed through the time of the complete alternative tactics projection.

f.  Projection times can range from 10 to 120 minutes.

Several display formats, similar to those presented earlier, have been specifically designed to present the comparative alternative tactics information.  Figure 11 shows an approach geoplot display format for alternative tactics.  The geographical plot area, in this particular example, is presenting three different alternatives for ownship as indicated by the three track projections in the figure emanating from the ownship position.  No alternative actions for the target are projected in this particular example, with the resultant target track projection based on the target's current speed and course.  The right side of the display format presents six PI and tactical variable parameters for each of the three alternative options (i.e., Option A, B, and C), enabling their comparison for each alternative set.  The PIs and tactical variables displayed in this data area are selectable.  In the particular example presented in Figure 11, the data in the blocks represent the values at the ends of Legs 3, 5, and 5 for the three alternative sets (i.e., options A, B, and C), respectively. For example, range to the target at the end of Leg 3 under Option A would be 6,344 yards; range to the target at the end of Leg 5 under Option B would be 24,114 yards; range to the target at the end of Leg 5 under Option C would be 16,800 yards.  Coordination between the geoplot tracks and the data blocks is also color coded to facilitate analysis.

3.2.6  INSTRUCTOR CUES.  Cue information is provided to the instructor in real-time via the instructor remote console in the attack center during an exercise scenario.  The alphanumeric cue information is provided in a single line at the bottom of the CRT display.  Several types of cues are provided by SMARTTS:

a.  Notes -- Notes are cues that have been embedded in the script of each exercise scenario prior to the start, such that they are displayed at predetermined times.  An example of a note is the listing of trainee objectives that is displayed after initiation of the exercise.

b.  Alert -- An alert is a cue provided to the instructor on the basis of one or more events occurring during the scenario.  The alert times are not predetermined, but rather depend upon the occurrence of particular events.  For example, an alert may be given when the probability of counterdetection exceeds a predetermined level (e.g., 50 percent). Likewise, an alert would be given when the automatic interactive target initiates a maneuver.  The instructor can preselect the threshold value that triggers the alert.

c.  Alarms -- Alarm cues are given following a SMARTTS fault.  An example is when a particular display device is out of order, or when the SMARTTS-to-MSCG linkup can not be accomplished.

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APPROACH GEO
TIME:01:41:00
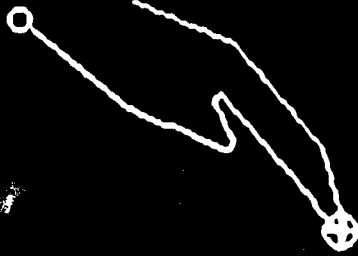
OPT B LEG 5

| SAR | ***** YD |
| CRALS|| | 0% |
| RH | 24114YD |
| SAS | 0 0KT |
| CRILS|| | 0% |
| SNR | -11 8DB |

OPT C LEG 5

The cues are displayed as they occur, and in a priority order (e.g., alarms have the highest priority, with notes having the lowest priority). When multiple cues are received they are stored in order in a file, with the highest priority and earliest cue presented on the screen. After the instructor acknowledges a particular cue, it is removed from the screen, and the next cue in line (i.e., if additional cues exist) becomes displayed. Cue information assists the instructor in several ways: first, by storing predetermined notes for him to be brought up at appropriate times during the exercise scenario; and second, by monitoring critical events during the exercise scenario, and thus reducing the instructor's monitoring load.

3.2.7 EXERCISE LIBRARY. A set of exercises to support a set of tactical training objectives has been developed under SMARTTS. These exercises, including all relevant parameters, are stored on the computer. To initiate an exercise, the instructor can select the desired exercise via the IRC and have it automatically loaded and initiated on the trainer. This capability greatly reduces the amount of time the instructors have typically spent manually loading the various parameters necessary to setup an exercise scenario.

Many aspects of the exercise scenario can be previewed by the instructor prior to loading on the trainer. The instructor has the capability to modify significant tactical parameters immediately prior to their automatic loading. If he chooses to modify scenario parameters, he can then save the exercise scenario if so desired, and add it to the exercise library. In this manner, as new exercises are manually developed either off-line or immediately prior to initiating an exercise scenario for a particular group of trainees, they can be readily added to the exercise library for later selection and automatic loading.

3.2.8 TIME FLAG UNITS. Six time flag units are available in the attack center, five of which are allocated to trainee operator stations and one allocated to the instructor's console. The time flag unit is a small button which can be pushed by trainees and the instructor at any time during an exercise scenario. The time at which each time flag unit is pushed is automatically recorded in the SMARTTS data base. These times can later be retrieved during playback in various ways. They serve to indicate a point in the exercise scenario at which the instructor and/or trainees wish to discuss some issue. In essence, they serve as a cue during playback.

3.2.9 AUTOMATIC INTERACTIVE TARGET. The vast majority of SMARTTS capabilities are aimed at supporting the training-related aspects of the training device and training system, as discussed above. SMARTTS generally does not provide capabilities to improve the simulation aspects of the training device. The automatic interactive target (AIT) is an exception, in that its characteristics serve a dual purpose: (a) to reduce the instructor's work load (i.e., analyses have shown that the instructor spends a considerable amount of time in controlling the targets), and (b) to improve the simulation quality of enemy targets. The automatic interactive target is a computer controlled target model. This model is composed of a

decision structure for an enemy submarine platform. The AIT characteristics were developed from the best intelligence information available to the SMARTTS project concerning the particular submarine platform implemented. The AIT acts as an intelligent adversary, whose ship has capabilities equivalent to those of the actual at-sea enemy submarine platform. The AIT reacts to ownship's actions, as he would be expected to receive information through the environment and intelligence sources, interpret that information, and select his tactical actions. The manual method of controlling target actions by the instructor, may have undesirable effects, such as instructor bias in his perception of target actions and their probability of occurrence; it also creates some competition between the instructor/target and the ownship team during the exercise scenario. Although manual control of the target by the instructor may be necessary in certain operations, the AIT can often alleviate instructor control and present a probabilistically realistic target.

The AIT structure is based on a dynamic probabilistic decision model. A high level overview of that model is presented in Figure 12. This diagram shows major decision points that occur throughout the exercise scenario, for which alternative sets of target actions are associated. The AIT has three levels of competency, ranging from basically capable to highly capable. The actions available to the AIT, and their probabilities of occurrence, are keyed to the AIT's level of competence as well as other factors (e.g., operational mission). The typical mission evolution of the AIT would initiate at the top of the block diagram beginning with the block (see Figure 12) tactical parameters and follow through based on events that occurred during the scenario, the information received and its interpretation on a probabilistic basis by the AIT, and the action selected on a probabilistic basis. The typical exercise would likely follow through to either evasion or attack.

Information regarding AIT sensor monitoring and tactical activities is provided to the instructor for overseeing the target actions. Alerts are provided on the instructor's console in the attack center informing him of decisions being made by the AIT, and impending AIT actions. The instructor can override planned actions of the AIT prior to their occurrence. The instructor can also initiate preset actions by the AIT, such as starting a particular baffle clearing sequence. In this manner, the instructor is not overburdened by evaluating in detail the actions of ownship, their impact on the target, and the actions the target should take, but rather has his target control work load reduced to primarily a monitoring function, with override action if necessary.

The AIT performance profile is controlled by a role situation and mission assignment. This initializes AIT processing so that all tactical actions, reactions are consistent with the assigned role situation and mission as follows:

a. Role situations are (1) peacetime or (2) wartime.

b. Basic missions are (1) transit or (2) antisubmarine warfare.
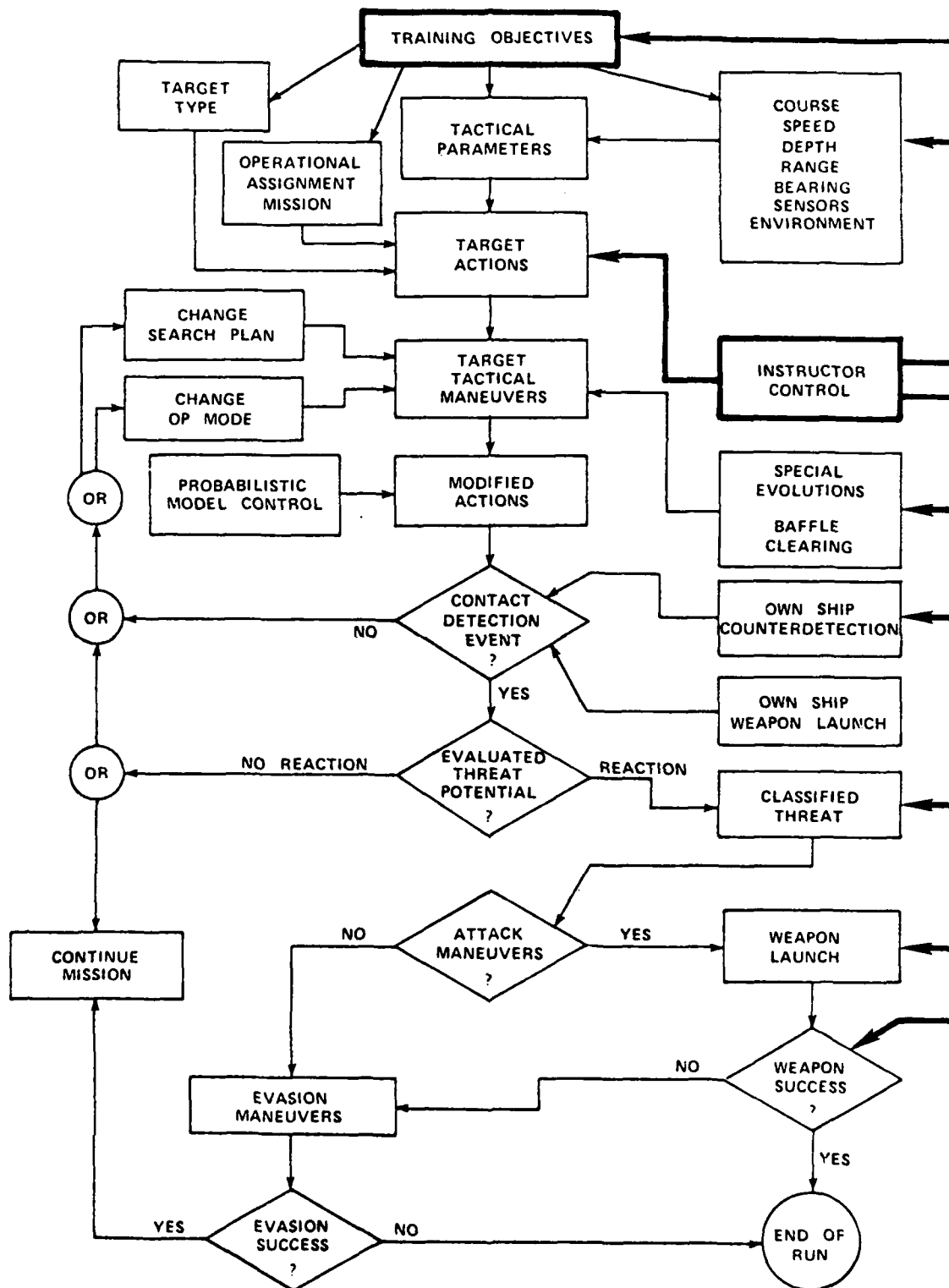
Figure 12. Overall AIT operation

The major maneuvering sequences available to the AIT, of which alternative sets of actions will occur on a probabilistic basis, are:

a. Transit tracks

b. Patrol search pattern

c. Periscope excursion

d. Baffle clearing pattern

e. Target detection events

f. Approach and torpedo sequence

g. Surviellance sequence

h. Torpedo evasion and avoidance sequence

i. Target evasion sequence

3.2.10 TRAINING SUPPORT MATERIALS. A variety of materials have been developed to support the tactics training process using SMARTTS, as well as operation and maintenance of SMARTTS itself. These include the standard system operator's manual, maintenance manual, and other supporting documentation. They also include an operators course and maintenance course. Two additional sets of support materials have been developed to better ensure effective use of SMARTTS and an effective tactical training process. These consist of (a) an instructor's handbook and training course aimed specifically at instructional methodology, and (b) tactics training material to support the initial courses to be conducted under the SMARTTS configuration.

An instructor's course and handbook were provided in addition to the standard operator's course for SMARTTS. Instructor personnel completed the operator's course which addressed the operation of SMARTTS in conjunction with the 21A41A SCST. The instructor's course went the next step in addressing how to provide effective training utilizing the SMARTTS characteristics. Topics included in the instructor's course and the instructor's handbook are:

a. Training process structure (Figure 13)

b. A recommended tactics training sequence

c. Description and application of training techniques

d. Exercise selection

e. Specific tactical courses

f. Conduct of preexercise and postexercise briefings
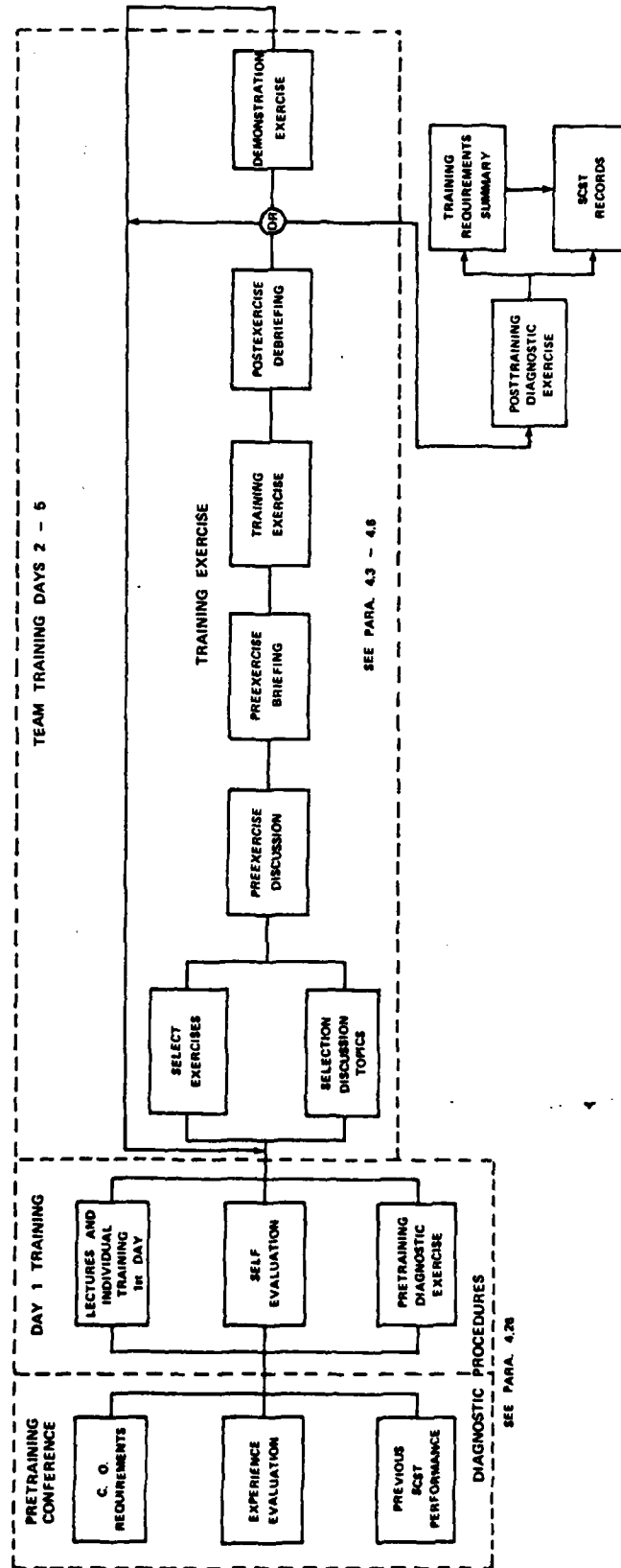
Figure 13.  The training process

g.  Instructor qualifications

h.  Instructor functions

i.  Learning principles applicable to team training

j.  Team and individual training

k.  Positive and negative feedback

l.  Application of training principles

m.  Training techniques and their application (e.g., positive guidance, demonstration, immediate repetition, experience enhancement, direct exposure, common error, team awareness)

n.  Appropriate use of SMARTTS characteristics during the training process

o.  Diagnostic procedures

p.  Performance data analysis

q.  Team self-evaluation

The tactics training course material was developed as a model of the application of SMARTTS characteristics to the conduct of tactics training. Tactical exercises and supporting materials were developed for use by Navy instructors to conduct tactics training using SMARTTS. These materials represent only the initial application of SMARTTS. The tactics training sequence in Figure 14 provides an overview of the structure for the tactics training course material developed.

The intention of the instructor's course and the tactics course was to provide the complete training system media to achieve effective tactics training for the initial application. It is, unfortunately, atypical for an instructor's course to actually address instruction rather than operation, and for a tactics course to be provided along with the training device. However, it is believed that this is certainly the most cost/effective approach since the Navy is provided with an applied example of the system's application along with support material, a course and handbook on how to effectively use that system to conduct training, and information addressing how to evolve the system further. The success of SMARTTS and any training system depends primarily on the effectiveness of the instructor. Not only must the instructor be effective in conducting the training exercises, but also in the development of the exercises, the providing of feedback, and the assessment and upgrading of the training program.
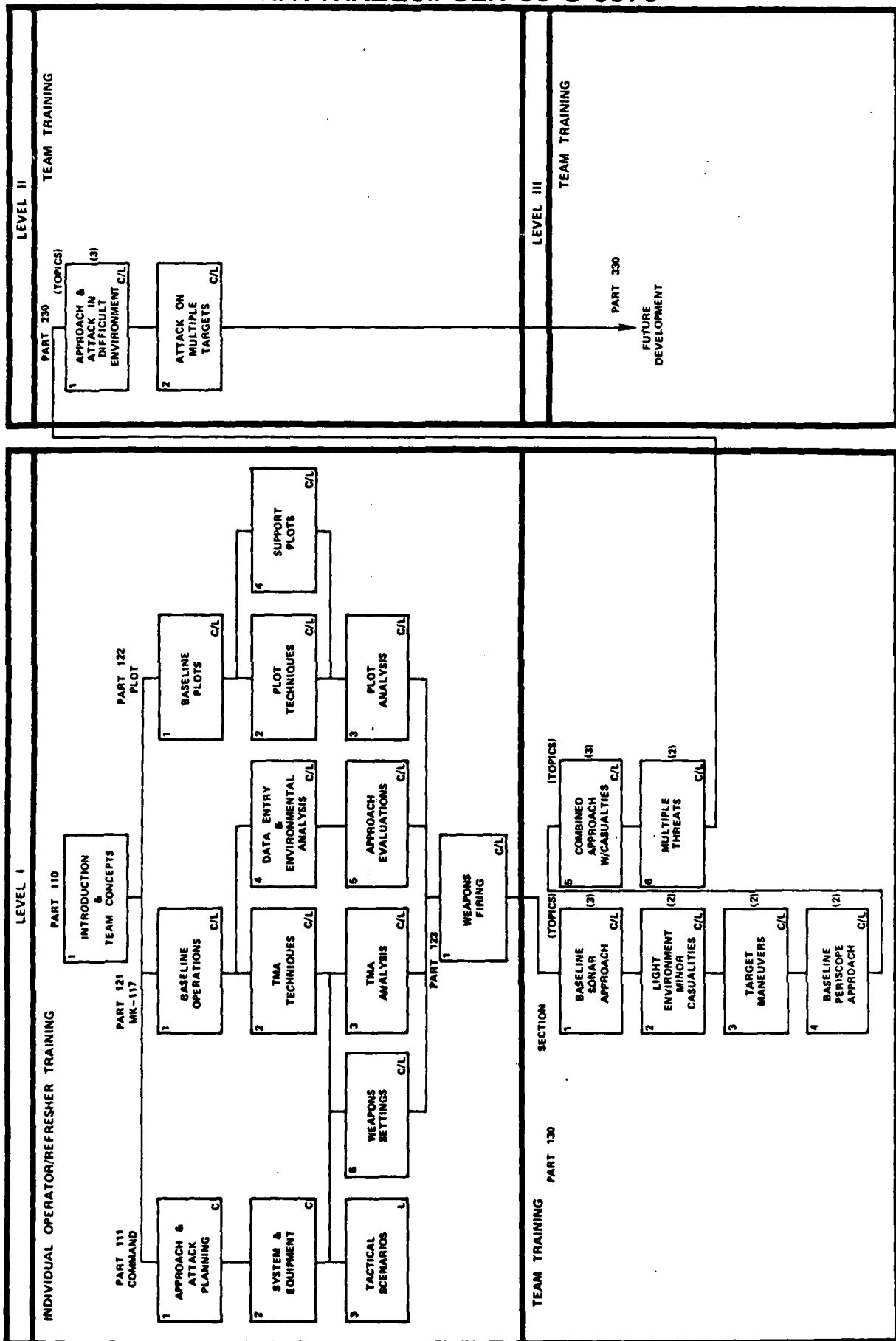
Figure 14. Training sequence chart – preprototype training

## 3.3  SMARTTS SOFTWARE

The SMARTTS software consists of three major components; (a) software resident in the SMARTTS host computer, the VAX 11/780; (b) SMARTTS software modifications to the Device 21A41 Submarine Combat System Trainer, Main Simulation Computer Group (MSCG); and (c) modifications to the MK117 fire control system operational programs data gathering module.  The major set of software is contained in the SMARTTS host computer, which performs the majority of the SMARTTS functions.  Modifications to the existing MSCG software are for the purposes of (a) collecting data from the MSCG (e.g., ownship sonar parameters); (b) to insert instructor commands from the IRC in the attack center (e.g., AIT maneuver commands); (c) to provide problem control/status information to the IRC for monitoring by the instructor; and (d) to enable automatic loading of the scenario from SMARTTS to the MSCG. The software modifications to the MK117 fire control systems operational software data gathering module were made for the purpose of collecting data from the MK117 for performance evaluation and feedback purposes (e.g., target motion analysis system solution data).  Whereas, the MSCG modifications involved two-way communication, the MK117 fire control modifications were one-way (i.e., data out of the MK117 to SMARTTS).

The software structure is highly modularized to facilitate maintenance, modification, and upgrading.  A detailed discussion of the SMARTTS software is beyond the intention of this report.  A brief summary of the functions performed by each of the 17 SMARTTS software modules is provided in Appendix B.

SECTION IV

PRELIMINARY CONCLUSIONS


The initial SMARTTS installation has been setup as a preprototype of training assistance technology (TAT), to be evaluated under operational training conditions. The intention had been to have SMARTTS undergo a 6-month test and evaluation phase, after which a decision would be made regarding the training effectiveness value of each SMARTTS characteristic. The exact form of the SMARTTS test and evaluation has not been decided upon as of this time.

The SMARTTS preprototype unit has been installed on the 21A41A submarine combat system trainer in Norfolk, Virginia. The SMARTTS preprototype has been used in operational training exercises since its installation, and has been demonstrated to various groups of naval training personnel. Since the SMARTTS evaluation has not yet taken place, it would be premature to address the effectiveness of SMARTTS as a whole, or of its individual capabilities. A summary of several preliminary observations are appropriate at this time, however.

The training capability and engineering development aspects of the SMARTTS preprototype have been carried out successfully, as intended. The preprototype unit was designed, developed, and installed as planned. The various courses (i.e., instructor's course, maintenance course, operator's course) have been conducted. In essence, the system has been delivered to the Navy. SMARTTS is currently being used, as part of the 21A41A SCST, in support of a wide range of submarine tactics training. Most SMARTTS characteristics have been actively used to support operational training; the use of certain characteristics has depended on several factors including the group of trainees and the particular exercise scenarios.

The submarine tactics training fleet project team has observed SMARTTS, and discussed its potential. Their preliminary observation was favorable towards the potential training effectiveness of the various SMARTTS characteristics. This viewpoint was based on a preliminary observation of the SMARTTS characteristics, and not observation of their use during the training process. As noted above, the fleet project team will make a final evaluation of the effectiveness of each SMARTTS characteristic after SMARTTS has been used in training over an appropriate period of time. Plans are currently being developed for the conduct of that evaluation.

The capabilities provided on the preprototype SMARTTS have been determined as necessary to improve the cost/effectiveness of tactics training. These capabilities represent the application of good training technology, and hence should be incorporated to a greater or lesser extent on most simulator-based training devices. The early enthusiasm which the SMARTTS preprototype has generated attests to the validity of training assistance technology as a necessary part of every training device/system.

## SECTION V

## RECOMMENDATIONS

The SMARTTS preprototype, as a research and development tool, provides a testing ground for a variety of training assistance technology characteristics. A variety of additional TAT characteristics have been identified, but not included in the preprototype. Furthermore, during the development of the SMARTTS preprototype and its limited operation and evaluation at the site other important training-related issues have come to light, many of which might fall under the guise of TAT, while others are important related issues. These issues are relevant to the cost/effective design and operation of training systems. They require a varying mix of research and development efforts, by the Navy, (e.g., NTEC) and contractors, with investigation in the laboratory and in an applied training setting. Of those associated with TAT, many are implemented in the SMARTTS preprototype, others are considered as important candidates for upgrading (i.e., planned evolution) the SMARTTS preprototype, and others are being considered to be added as part of the SMARTTS-type characteristics that will become part of the next generation of SCSTs. Other issues may be associated with SMARTTS, but not directly a part of it. It is important that these training-related issues receive the necessary investigative emphasis, with the continual evolution of the training system to continually achieve improved levels of cost/effective training.

## 5.1 RESEARCH AND DEVELOPMENT PLAN INTRODUCTION

A research and development plan has been devised to identify the relevant research and development issues, and to recommend an approach to their solution. This research and development plan is not intended to be the perfect approach to resolution of this large variety of issues. Rather, its purpose is to identify and organize the myriad of relevant issues, and to identify a plausible structure within which they can be acceptably addressed. The number of issues are vast, to the point that it is unlikely all can be addressed in the near future. Hence, it is expected that more detailed research and development plans will be developed to address particular areas identified herein, and to further delineate the specific issues to be addressed under each (i.e., including time scheduling, and so on). This research and development plan is intended to provide the first-cut high level overview of an approach to the continuing investigation of training assistance technology, and its associated issues with regard to the development of cost effective training systems.

Several fundamental dimensions pertain to the organization of the plan, and how it might be carried out. The brief discussion of these dimensions, and the following detailed recommendations, has been developed to provide information regarding this author's opinions concerning the organization and implementation of a research and development plan addressing Training Assistance Technology. An extensive analysis of current training needs and other relevant considerations has not been formally performed. Rather, the

recommendations provided herein reflect the experiences and background associated with TAT, SMARTTS, and other training research and development work. It is expected, therefore, that these recommendations will form one of several information sources used to evolve and update current research and development plans. The fundamental dimensions of the plan are identified below and discussed in the following paragraphs:

a. Work area -- Three major areas have been identified: (1) 21A41A site work, (2) training assistance technology work, and (3) other related work.

b. Work type -- Basic research, applied research, development to refine existing capabilities, development to add new capabilities.

c. Location -- Site work to be performed at appropriate operational training sites; (e.g., 21A41A SCST) and laboratory work to be performed in a laboratory setting, with an appropriate apparatus configuration (e.g., Navy laboratory; contractor's laboratory).

d. Application -- Direct training process function, or training support function.

The work area was selected as the primary dimension for organization of the research and development plan. The preprototype SMARTTS installation on the 21A41A SCST provides an onsite research and development capability which has the potential of providing extremely valuable information regarding the cost/effectiveness of training system characteristics. Each time a training exercise is conducted at the site, empirical data is generated regarding the use of various SMARTTS characteristics, the effectiveness of the training exercise, and so on. It is important that the Navy take advantage of this extremely important information. Onsite research has an extremely important role in the R&D process, since it can provide the end-product data for evaluation of training system characteristics in the applied training setting. Hence, the first major segment of the research and development plan addresses the onsite work. The second work area, TAT, addresses a variety of characteristics identified within the SMARTTS program. Many of these characteristics are included in the preprototype SMARTTS, while others have been identified but not yet implemented. This second work area category of research and development addresses those characteristics considered as a part of TAT. The final work area category (other related work) addresses a variety of important training issues not in the other two categories. The technical elements of the research and development plan are addressed under each of these three major work areas, comprising the bulk of the plan.

The work type to be performed is an important secondary dimension. It has a direct impact on the priority of work to be performed, with considerations for the time frame to conduct the work, the selection of who should perform the work (e.g., Navy laboratory, contractor). It also impacts where the work should be performed, at the site or in a laboratory, the type of personnel, and funding sources.

The location dimension addresses the recommended setting, for performing the work, at the training site or in the laboratory. This dimension

overlaps, to some extent, with the work area dimension identified above and with the other dimensions. However, it also provides independent information. The location is particularly sensitive to the work type. Basic research should usually be performed in the laboratory; it should identify those TAT concepts and characteristics that have potentially high training value. Applied research should also be performed in the laboratory, when cost-effective, so as not to interfere with operational training. Often, however, the requisite applied research can only be conducted at the operational site. Development work, like applied research may be best accomplished in both locations.

Careful consideration must be given to the performing organization (Navy, contractor). This dimension generally focuses on the resources available to perform the necessary work in a timely and cost/effective manner. The three above dimensions have a direct impact on the selection of the performing organization. Navy laboratories and contractors each have unique capabilities and limitations, which should be carefully considered in determining the performing organization. Factors to be considered include: (a) interface with the operating forces (e.g., operational experience of team members; protocol); (b) resident basic and applied research skills, and previous experience; (c) subject matter expertise; (d) proximity to data collection sites, including accessibility to necessary technical information; and (e) specific prior work (e.g., the SMARTTS system developer should perform the system modifications). It is beyond the scope of this research and development plan to recommend performing organizations (even generically) for the various elements. Hence, this dimension will not be addressed further in this plan.

The products emanating from work addressing elements of this plan may be directly related to the conduct of the training process (e.g., feedback displays), or may be of an indirect training process support nature (e.g., long-term analysis capabilities). This application has an impact on the priority allocated to the various elements of this plan. Generally, those elements directly impacting the training process have been given a higher priority.

The work area represents the primary dimension for addressing the elements of this plan. The other three dimensions are secondary, although also relevant to categorization of the work. The research and development plan has two major parts: (a) identification of research and development issues (Section 5.2) and (b) a research and development plan summary (Section 5.3) . The first part describes, in some detail, each of the 101 recommended issues. This part groups the issues under the three work areas. The plan structure is summarized in Figure 15, showing each of the three work areas, and their major issue categories respectively. The discussion in this first part addresses the issues under each of these categories. This is the most essential part of the plan since it identifies all the research and development issues. The second part of the plan provides information about each of the other dimensions, pertaining to each issue (e.g., priority, estimated cost). This information is mostly presented in tabular form in Table 1, and discussed in the research and development plan summary contained in Section 5.3.

WORK AREA*

5.2.1**

21A41A Site Work

5.2.1.1 Test & Evaluation (1)+
5.2.1.2 Refine SMARTTS (2)
5.2.1.3 Add TAT Capabilities (17)
5.2.1.4 Test & Evaluate New TAT
Capabilities (49)
5.2.1.5 SCST Survey (50)

5.2.2

TAT Research and Development

5.2.2.1 AIT (51)
5.2.2.2 Alternative Actions (57)
5.2.2.3 Performance Indicators (58)
5.2.2.4 Information Presentation (65)
5.2.2.5 Processing Support (73)
5.2.2.6 Instructor-Specific Charac-
teristics (80)
5.2.2.7 Trainee-Specific Character-
istics (90)
5.2.2.8 Training System Management (96)
5.2.2.9 TAT Guidelines (97)

5.2.3

Other Areas

5.2.3.1 Gaming (98)
5.2.3.2 Training Methodologies (99)
5.2.3.3 Training Effectiveness Measure-
ment (100)
5.2.3.4 Embedded/Organic Training (101)

* Plan is structured around the Work Area Dimension
** Number refers to section number in the text
+ Numbers indicate research issue for correspondence between text and Table 1

Figure 15. Research and development plan structure (major issue categories shown)

## 5.2 RESEARCH AND DEVELOPMENT ISSUES

Recommended Research and development issues are identified and described below under the major work area categories of 21A41A site work (Section 5.2.1), TAT research and development (Section 5.2.2), and other areas (Section 5.2.3). Each work area is organized into several major subareas pertaining to specific TAT capabilities investigative issues. Specific elements of work are addressed under each subarea.

Note, each of the 101 research and development issues is numbered consecutively in the order presented in this plan. This number provides correspondence with the listing of issues in Table 1, which provides information relevant to the other fundamental dimensions of part of this plan (note, Table 1 is discussed in the subsequent part of this section, Research and Development Plan Summary, Section 5.3).

5.2.1 21A41A SITE WORK. The installation of the SMARTTS preprototype as part of the 21A41A provides the Navy and NTEC with an excellent opportunity to conduct empirical research in the applied training environment. The initial plans during SMARTTS development were to install a preprototype SMARTTS as part of the 21A41A, to evaluate the effectiveness of each of the SMARTTS characteristics, and to modify the characteristics as necessary leading to the design specification for the SMARTTS prototype unit. This thrust of work remains a major recommended part of the work to be performed under this area. Other work is also recommended to be performed under this area in conformance with need and site availability.

5.2.1.1 <u>Preprototype Test and Evaluation.</u> (1) The preprototype SMARTTS should be evaluated during operational training. Aspects of concern during this evaluation are:

    a. The overall TAT concept as exemplified by SMARTTS in a generic sense.

    b. Each specific SMARTTS characteristic:
- As currently implemented on the 21A41A.
- With regard to its impact on submarine tactics training effectiveness.
- With regard to its likely impact on training effectiveness in other applications.

    c. SMARTTS characteristics should be modified as necessary during the evaluation period to insure that the evaluation considers the true potential of each characteristic, rather than being constrained by the particular manner in which it has been implemented in this initial application.

    d. The opinions of the instructional staff along with objective evaluations should constitute the data base for the investigation.

    e. The evaluation should be conducted over a period of months to insure that the instructional staff has adequate familiarization with the application of the various SMARTTS characteristics.

f. The amount of utilization of each SMARTTS characteristic should be assessed (e.g., number of times used per exercise, total number of minutes used per exercise). This should form one source of information for evaluation purposes, and to direct modification efforts.

g. As rigorous a methodological approach as possible should be followed for this evaluation.

5.2.1.2  Refine SMARTTS.  (2)  The SMARTTS characteristics are largely implemented via the man-machine interface, for which relatively little objective data has been available to guide design practices.  Although the generic SMARTTS characteristics stem from an extensive training analysis, the specific interface characteristics (e.g., specific display formats) have been largely organized on a basis of "good human factors design".  They have not, however, benefitted from an in-depth human factors analysis regarding the particular operational sequences, etc.  It is expected, therefore, that substantial improvements in the interface characteristics can be made, as experience is gained, to substantially improve instructor functioning.  An example is the command sequences for various functions on the plasma entry device.  If appropriate empirical data were available regarding the particular sequences that the instructor is likely to use, a more effective design could be achieved.  It is recommended, therefore, that an investigation be conducted to identify specific aspects of SMARTTS that would benefit from refinement of the man-machine interface.  Several specific research elements are:

a. (3) Refinement of the cursor control on the displays, such as the trigraph and time function plots.

b. (4) Provision of a visual indication for the audible plasma signal.

c. (5) The interactive sequence with the plasma entry device may be substantially improved if it is tailored to the likely actions of the instructor.  For example, those operations most often performed by the instructor should have the shortest series of plasma entry steps.  Data for this analysis could be conducted from discussion with the instructors; also, an automated routine could be inserted into the SMARTTS software to automatically monitor the sequence of input commands made by instructors. The entry sequence could be reformatted to minimize the number of steps required overall.

d. (6) Plasma entry sequence should be modified to allow the instructor/operator to manipulate the scaling parameters of the approach geodisplay format (i.e, range scale, and plot center) without having to re-enter the command tree each time.  This would greatly facilitate manipulation of the display by the instructor to achieve the desired picture.

e. (7) Evaluate the system response time for various entry commands to identify those entry commands that take too much time.  The entry routine should be modified to speed up the system response to these commands.

f. (8) Investigate a means of identifying each target on the approach geoplot display (e.g., joystick for positioning of a cursor over a target) and obtaining an alphanumeric readout of the target characteristics.

g. (9) Investigate the use of the alternative tactics characteristics from an interface standpoint, leading to redesign of its operation. The alternative tactics feature as currently implemented appears to be somewhat time consuming. Partially automating this capability may help, such as providing three programmed alternatives associated with each library exercise. Other ways of manipulating the CRT plot (e.g., allowing the instructor to simply point to the position he wants ownship to move to, and having the computer calculate the necessary course and speed change and other variables) should be investigated. Note, the alternative tactics capability is also identified under additional TAT capabilities relevant to site work (Section 5.2.1.3, #17), and addressed in greater detail under TAT research and development, alternative actions (Section 5.2.2.2, #57).

h. (10) The actual ownship action taken in a particular problem should be automatically presented as one alternative when engaged in an alternative tactics investigation. This would enable the other selected alternative actions to be compared with the actual tactical action followed by ownship without the necessity of manual entry by the instructor.

i. (11) Investigate the use of color on the information displays to determine the most effective principles of application. For example, perhaps use color to distinguish the difference between friendly and hostile forces. Also, the use of color may differ for various applications, such as monitoring and control of the training exercise scenario versus presentation of feedback information in the classroom.

j. (12) When a new target of interest is selected, the current display formats being presented should automatically change to present the appropriate information relevant to the new target. Re-entry of the command sequence is currently necessary to bring up the display format for the new target.

k. (13) Add the capability to shift ownship to various vessels in the exercise scenario from the instructor's console.

l. (14) Add a "hard copy" switch on the plasma such that the instructor can remotely activate the hard copy unit to copy the CRT image.

m. (15) Automatically enter the subjective performance indicator when selected by the instructor. At present, the instructor must push an additional entry button after he has indicated the performance indicator selected.

n. (16) An investigation should be conducted to determine if the performance indicators CRILS and CRALS should be referenced to the selected target position or the predetermined firing point for that particular target. Differences of opinion currently exist.

5.2.1.3  Add TAT Capabilities.  (17)  Modification of the existing preprototype SMARTTS characteristics should be accomplished to overcome current inadequacies, and to further evolve the system capabilities.  Each of these modification classes will result in a more effective training system.  Whereas the previous issue (i.e., refinement) addresses the tuning of the preprototype characteristics, this issue addresses the addition of new characteristics to the preprototype.  Obviously, there may be considerable interpretation with regard to refinement versus addition of new characteristics.  Refinement, as used above, has generally meant the improvement of existing characteristics, while this section is addressing the implementation of additional characteristics.  The recommended elements are as follows:

a.  (18)  A capability should be added to facilitate the modification of PIs and the addition of new PIs by instructor personnel.  Although the SMARTTS software structure facilitates modification this can currently be achieved only if the instructor is well versed in the SMARTTS software and its modification.  One means of providing the instructors with this capability is via an instructor interface language, which is discussed in more detail under the TAT area, instructor specific (#82).  This capability should be provided to instructor personnel via the model deck VT100 terminal.

b.  (19)  Additional PIs should be developed and added to the SMARTTS repertoire.  A major aspect of SMARTTS during the design was its capability to evolve as the training situation evolved.  PIs should be modified and/or added as necessary to support effective tactics training.  The research and development of PIs is both a site issue and a TAT research and development issue.  Several specific PI recommendations have been made by 21A41A site personnel; these should be readily implemented.  In addition, a long term research and development effort should be initiated for the continual development and upgrading of PIs; this is discussed later under the TAT area, Performance Indicators, Section 5.2.2.3, #58.  Specific PIs that have been suggested, and are recommended to be implemented at the site, include:

- Towed array stabilization times as a function of speed
- MK48 torpedo detection/acquisition range
- Probability of weapon hit
- MK48 presets -- tactical variables rather than PIs

c.  (20)  The tactical effectiveness factor (TEF) should be investigated to determine if it can be implemented via SMARTTS.  The TEF is used by COMSUBLANT to provide an estimate of a ship's tactical ability, based on observation of at-sea exercise performance across different units.  The TEF parameter may provide relevant information during training since several performance indicator-type parameters are associated with the calculation of TEF.  Each of these individual parameters may also be relevant as PIs during the training exercise, and should thus be investigated.

d.  (21)  A time/frequency plot should be developed for presentation of feedback information.  The information that would be addressed on this plot is directly relevant to an important aspect of tactics training.  The information necessary to construct the plot is readily available in the simulation computer.

e. (22) The geoplot feedback display should be investigated for modification, or for the development of an additional related display. The current geoplot feedback display appears effective as currently configured. Hence, it may be desirable to develop a similar display with the additional necessary information to further support the tactical training objectives and provide necessary feedback. Recommended modifications include:

- Extend bearing lines beyond the actual target, showing maximum range for estimated speed.

- Superimpose the actual bearing lines on the display (i.e., buzz bearings and automatic target following bearings).

- Provide indication on the display for the minimum/maximum ranges, Ekelund ranges when determined, and other range related solution data.

- Additional parameters may also be added to this display format, including readouts addressing target range, range rate, and line-of-sight information.

f. (23) The applicability of an information display format showing multiple line-of-sight diagrams to several targets should be investigated. This display format would present up to four line-of-sight diagrams from ownship to selected targets. The line-of-sight diagram is an integral tool used during submarine tactical engagements to evaluate the geometrical relationships between ownship and the various targets. Multiple line-of-sight diagrams would be useful during an encounter with several targets simultaneously.

g. (24) The capability should be added to enable the designation of any target as the source of information for generating the display formats. That is, as currently configured, the line-of-sight diagram, PIs, and tactical variables presented on the display formats pertain to only the primary target. The capability should be provided in SMARTTS to enable the instructor to designate any target as the source of this information. Hence, the instructor, and/or trainees, could view the various display formats and information summaries as pertaining to any of the targets included in the problem.

h. (25) The effectiveness of providing a line-of-sight diagram from ownship's weapon (e.g., torpedo) to the target should be investigated. It appears that this display format may be a useful training aid with regard to controlling the weapon postlaunch.

i. (26) An investigation should be initiated to develop a time/range plot providing relevant summary information relating to the system solution, the system solution range error (i.e., PI), and the actual range. The display format should be developed to integrate these important tactical variables and PIs to present an effective feedback picture relevant to evaluation of the amount and direction of target motion analysis errors, and range relevant to the firing point.

j.  (27) A signal to noise ratio (SNR) versus time plot linked to the different modes of the AN/BQQ5 sonar operation, should be investigated as an addition to SMARTTS for feedback purposes.  This plot would specifically pertain to the 50% probability of detection SNR limits.  The format would present a plot of actual SNR over time of the exercise, with the relevant recognition differential levels indicated.

k.  (28) The symbol repertoire of the SMARTTS displays should be expanded to include additional NTDS symbology (e.g., friendly and target helicopters, sonar buoys, and decoys).

l.  (29) A feedback display should be developed to present the torpedo vertical and horizontal plane search position versus the target's position. This display would provide information to the trainees regarding the torpedo track in the three dimensional environment, and its acquisition of the target.  Several relevant display concepts are presented later under the TAT area, information presentation (Section 5.2.2.4, #65), that address the use of three dimensional displays.

m.  (30) A depth option should be added to the alternative tactics capability, to permit examination of the impact of changing ownship depth relative to the target and the environment.

n.  (31) The alternative tactics characteristics are believed to be an extremely valuable tool to aid in the learning of complex relationships. The alternative tactics setup procedures used on SMARTTS, however, are somewhat laborious as compared with other SMARTTS operational procedures. It is recommended that an investigation be initiated to evaluate various approaches to the implementation of alternative tactics setup and control procedures.  For example, several relevant alternative ownship and target actions could be predetermined and stored on the training device; these could be automatically generated via a single button push command by the instructor.  Hence, the instructor would have rapid access to several relevant actions pertaining to each problem.  He would also be able to manually enter other alternatives as he so desired.  Other types of instructor interface characteristics should be investigated in this regard also.  Note, alternative tactics is also identified under refine SMARTTS, relevant to site work (Section 5.2.1.2, #2), and addressed in greater detail under TAT research and development, alternative actions (Section 5.2.2.2, #57).

o.  (32) Modifications to the approach/geoplot/line-of-sight display should be investigated with regard to the inclusion of periscope-related information.  The trainees obtain certain information during the periscope observation that can be compared with the similar computer-generated (i.e., actual) information.  The relevant parameters include target bearing, target angle-on-the-bow, target range, and time.  The actual computer-generated information can be provided on a display for comparison with that information manually collected by the trainee, and recorded by the instructor.  This information could be added to the approach/geoplot display.

p.  (33) Additional subjective PIs should be investigated relevant to periscope operation, following from the above recommendation.  During a

periscope observation the instructor could manually enter subjective information into SMARTTS via the instructor's console, based on the trainees observations. A comparison of the actual and the student-generated values could then be provided as relevant feedback information via one or more SMARTTS display formats. This is considered as an important aspect in tactical training (i.e., periscope operation). PIs should be developed and tactical variable information collected for airborne and missile platforms.

q. (34) Additional data should be collected from the MK117 fire control system pertaining to the actions of individual operators. Data relevant to the editing actions of the MK81 weapon control console operator, for example, would provide relevant feedback information. SMARTTS generally addresses the overall team and ship performance, and to a lesser extent the actions and performance of individuals. SMARTTS should be expanded to address in greater detail the actions of individual operators such that it can further assist the instructor in providing a more effective training process in this regard. This expansion should focus around the collection of appropriate data, the development of necessary performance indicators, and the development of appropriate display formats for monitoring by the instructor and for providing feedback and instructional guidance.

r. (35) The training material developed as a part of the preprototype SMARTTS should be expanded to provide greater coverage of submarine tactical training requirements. That is, the exercise library should be expanded along with the appropriate instructor and trainee guides to address a greater breadth of tactics training (e.g., over the horizon missile capability). The training material currently provided via SMARTTS addresses only the basic level of tactics training; intermediate and advanced level training material should be developed.

s. (36) Additional relevant tactical variable data should be collected from the MK117 fire control system. SMARTTS currently collects and presents as feedback information data relevant to target motion analysis (e.g., system solution accuracy). A variety of additional data are available for collection and presentation from the MK117 FCS. These include, for example, MK48 weapon presets. An analysis should be made of the complete set of relevant tactical variable data to be collected from the MK117 FCS, and SMARTTS modified to effect that collection. Appropriate feedback display formats would have to be developed to present the information as appropriate relevant to the various training exercises.

t. (37) The approach geoplot/line-of-sight display should be investigated with regards to modification for inclusion of additional relevant information. This display format has been used extensively during training to date. It should be investigated for inclusion of additional tactical variables and PIs. For example, probability of counterdetection and probability of detection rings could be placed on the display format as an additional source of information during exercise monitoring by the instructor, as well as for use during postproblem feedback sessions. Other relevant information, for example, should be investigated for inclusion on the geoplot display relevant to detection (e.g., detection limits for bottom bounce, direct path, and conversion zone).

u. (38) A variety of AIT status information is provided via SMARTTS displays. However, the AIT operation is complex, both in a real-time sense and from a logic/decision structure standpoint. The type, amount, and timing of AIT related information to be presented to the instructor should be investigated. Additional information relevant to (a) impending AIT actions, (b) the logic buildup leading to the selection of those actions, and (c) the options available to the AIT and forthcoming logic paths may be appropriate for display to the instructor and/or the trainees. AIT-related information is important from several standpoints: (a) the instructor requires a certain amount of information to oversee operation of the AIT, and directly control it if necessary; and (b) the logical operation of the AIT is instructive in itself, since it represents the composite structure of the best available intelligence information pertaining to the particular target. The SMARTTS information displays substantially address the first of these AIT uses; the adequacy of the information in this regard should be investigated, and modified as necessary. The second use of the AIT has not yet been addressed during training, although it is believed that the AIT would be an excellent tool for demonstrating actions of the various targets modeled. This aspect is discussed later under the TAT area, AIT (Section 5.2.2.1, #51). In either case, investigation should proceed to determine the information display requirements relevant to use of the AIT.

v. (39) The SMARTTS instructor consoles (IRC and CRC) provide a primary color graphics CRT display surface, and a plasma entry device that has the capability of use as a secondary display surface. Investigation should be initiated to determine if the need exists for an additional primary display surface added to the IRC and/or CRC. An additional instructor console display would allow the instructor to maintain status information on one display while investigating other relevant aspects on another display. The additional display surface could be added to the existing instructor consoles. The necessity for such a display is unclear at this time, hence an investigation is suggested to determine the effectiveness and feasibility of an additional display surface.

w. (40) An additional display surface is recommended for information presentation in the classroom, in addition to the large screen display. A major aspect of SMARTTS is its ability to provide information feedback (and prebriefing information) in visual formats to the trainees in the classroom. The need currently exists to simultaneously view several display surfaces, at times (e.g., approach geoplot display to provide a picture of the evolving geometrical situation, together with a trigraph display of PI's and tactical variables). The SMARTTS display formats have been designed to provide as much relevant information as possible on a single display surface, without overloading the visual presentation (i.e., in some cases such as the trigraph display the total amount of information available for presentation, if selected by the instructor, may exceed the trainee's limit to process). A second display surface in the classroom would enable additional information to be provided in a clear format. Hence, an additional display surface should be added.

x. (41) A display format should be developed to present information regarding the actual hand-computed Ekelund range solutions. That is, a computer generated Ekelund range solution based on the actual target

parameters, and sonar-received target parameters should be generated for comparison with the manual Ekelund ranges generated by the fire control party. An appropriate feedback display format should be developed for presentation of this information, or it could be added to the existing geoplot display format.

y. (42) A comprehensive freeze capability should be added to the 21A41A. SMARTTS has the capability to freeze. The remaining subsystems of the 21A41A (i.e., MSCG, MK117, and 21B64) can not completely freeze the problem. The capability of a freeze has been discussed for some time by the various groups concerned with submarine tactics training. This recommendation is currently being worked on by NTEC and other groups within the submarine training community.

z. (43) A weapon model capability should be added to SMARTTS to provide for classroom/standalone generation of weapon actions. In the SMARTTS standalone configuration (i.e., during prebriefing, in the classroom, etc.) the SMARTTS models can run an exercise problem in fast-time or real-time up until the point of fire, generating appropriate tactical variables and performance indicators. It is recommended that this capability be expanded to include weapon firing, postlaunch weapon control, evasion, and so on. It should be noted that SMARTTS does address weapon actions that took place in the real-time context during the attack center exercise (i.e., SMARTTS can provide feedback information relative to weapon actions). However, SMARTTS cannot address alternative tactics regarding weapon actions, nor address weapon actions in the standalone mode.

aa. (44) The Tomahawk and Harpoon capability should be added to SMARTTS. This would include the weapon modeling with regard to standalone operation as noted above, and also the development of relevant PIs, tactical variables, and feedback display formats. Employment of the Tomahawk and Harpoon will become a major focal point of tactics training in the relatively near future. Since Tomahawk and Harpoon represent an evolutionary step in the complexity of submarine tactics it is especially appropriate for SMARTTS training support.

bb. (45) The SMARTTS sonar and environmental modeling capabilities should be expanded to include other relevant aspects (e.g., convergence zone, the ability to select and simulate the various standard oceans, ocean layers, Lloyd-mirror effect and bottom bounce). The current models provide basic sonar and environmental capabilities; these should be improved to enable SMARTTS to address a wider range of training needs.

cc. (46) The capability should be developed to model additional target weapons to be fired against ownship. Similar to the need for providing for advanced ownship weapons in SMARTTS, the advanced target weapons should also be included to enable SMARTTS to provide the requisite state-of-the-art tactical encounters.

dd. (47) The AIT should be expanded to include additional relevant capabilities. Many of these have been identified in the initial specification of the AIT, but not implemented on the preprototype. Additional AIT capabilities include the conduct of a cruise missile attack,

avoidance activities, self-defense attack only activities, attack decoys, and so on. The priority of AIT capabilities to be added should be determined via discussions with appropriate naval personnel, with a long-term AIT development plan put into place. See the TAT area below, regarding additional discussions on the AIT (Section 5.2.2.1, #51).

ee. (48) The capability to control decoys should be added to SMARTTS and the main simulation computer group for use during the real-time attack center exercises.

5.2.1.4 Test and Evaluate New TAT Concepts. (49) The previous subsection addressed a wide range of new TAT capabilities for investigation and addition as a part of SMARTTS interface to the 21A41A SCST. A cohesive long-term investigative program should be developed to continually evaluate new TAT concepts implemented in tactics training. This should be a permanent program structured to continually upgrade the training subsystem of the training device. In particular, this program should receive those TAT concepts that have been found via laboratory research to have a high potential for improving the effectiveness of training. This program would then implement the selected concepts on a prototype basis, and evaluate these potentially effective concepts in the applied training setting, during operational training. This program should be viewed as a direct follow-on to the SMARTTS preprototype test and evaluation, recommended above. Appropriate data collection and evaluation capabilities should be added to SMARTTS in support of this program. Related capabilities to support this program are discussed further below under the TAT area, Processing Support (Section 5.2.2.5, #73) and Training System Management (Section 5.2.2.8, #96).

5.2.1.5 SCST Site Survey. (50) A formal survey should be made of all the SCST sites to identify training assistance technology characteristics that should be investigated for inclusion as a part of SMARTTS, or other training subsystems. The advent of SMARTTS has been a catalyst to the generation of training assistance technology concepts by the various members of the naval submarine training community. The site personnel have been exposed to the SMARTTS-type of technology and hence have generated a variety of ideas in this regard. The site survey should be the means for collecting, organizing and identifying relevant TAT concepts.

It is essential that the site survey be more than simply discussions with the various site personnel. Rather, a carefully prepared survey instrument should be developed that explores in-depth the range of training assistance technology, and facilitates the drawing-out of new concepts.

5.2.2 TAT RESEARCH AND DEVELOPMENT. The preprototype SMARTTS is the initial installation of training assistance technology characteristics. As such, it provides those feasible characteristics that appear to have the greatest potential for improving the effectiveness of submarine tactics training. Additional TAT characteristics have been identified in the earlier analysis work leading to the SMARTTS preprototype, although not implemented on the preprototype. Furthermore, those major TAT capabilities

implemented on the preprototype (e.g., performance indicators) are expected to evolve over time as the training situation and training technology evolves. The TAT area of research and development, as herein recommended, addresses the continual development of training assistance technology in the generic sense. Whereas the previous subsection addressed the specific development of characteristics pertinent to the 21A41A SCST and work to be conducted at that site, the recommendations in this subsection address the broader issues of TAT capabilities. Consequently, the recommendations in this subsection are typically of a broader nature, and not necessarily tied to submarine tactics training. These recommended research and development issues, which are generally considered to require laboratory research, should yield specific candidates for investigation in the field (e.g., as part of the 21A41A site research program). A broad range of research and development work would be conducted as a part of this category of the research and development plan, continuing the thrust to develop improved training assistance technology for enhancing the cost/effectiveness of training. Those TAT characteristics deemed ready for operational training, or operational training evaluation, would then move into the site work category, as represented by the above subsection.

5.2.2.1 <u>Automatic Interactive Target</u>. (51) The automatic interactive target (AIT) is a relatively new simulation concept. It has the potential of being the primary means for dissemination of intelligence information regarding target actions to the fleet. Furthermore, it can improve the effectiveness of tactical training by off-loading the instructor and thus providing him with more time for other aspects of the training process, and providing more realistic and representative target actions in response to ownship and the tactical situation. Finally, the AIT can provide a means for close analysis of the distribution of target actions on the basis of ownship tactics and other situational factors. A range of AIT capabilities have been identified as a part of an earlier analysis effort prior to development of the preprototype's AIT model. The preprototype AIT is a single target submarine with system capabilities and a decisionmaking structure modeled after a particular enemy target. This AIT model represents the initial step in the development of comprehensive AIT capabilities, pertaining to multiple targets, and so on.

It is recommended that a long-term research and development effort be initiated to evolve AIT models as an integral component of the training system. This long-term effort should include the following major parts:

a. (52) Identification and prioritization of AIT capabilities. This should include a time schedule plan for the development of AIT capabilities. Potential capabilities to be planned for should include:

1. Additional submarine targets

2. Multiple AITs in a single scenario.

3. AIT consort operations

4. Surface and air AITs

5. Battle group, convoy, etc., AITs

b. (53) The AIT models should be developed in accordance with the priority established above. This includes the collection of necessary intelligence information, the design or modification of decision structures, the development of algorithms, and testing of the model.

c. (54) The AIT models should be validated through empirical investigation in the applied training setting. These evaluations should not be aimed at identifying the acceptability or unacceptability of the AIT, but rather should be aimed at identifying the valid proportions and invalid proportions of the model, with an appropriate feedback loop to the AIT development process to assure modification and improvement of the models as necessary. The validation should be based on both intelligence information, and interaction with experienced submariners.

d. (55) The AIT/instructor interface should be closely investigated to provide effective monitoring and control, as necessary. This should include the identification of instructor information requirements and control requirements; the research and development of display concepts for providing necessary information; and the research and development of control concepts to enable the instructor to manipulate the AIT in various ways to achieve desired training objectives. For example, it may be desirable to provide a decision-tree diagram on a display format while the AIT is running so as to enable the instructor to keep track of the AIT's decision process. This display format may also be effective in classroom instruction regarding enemy target characteristics and actions. For example, the instructor may wish to dissect the AIT in the classroom to focus on subsets of the AIT's decision process and likely actions (e.g., demonstration of various baffle clearing maneuvers in a classroom context, with probabilities of different course changes on each leg of a particular baffle clearing maneuver).

e. (56) A procedure should be developed for the timely collection of recent intelligence information, and its transposition into an updated AIT model. This would have to be done on a regular basis between naval intelligence and training activities to transfuse the most recent intelligence information into the models, and transmit that to the respective sites. Regular AIT update loads should be provided to each site on a periodic basis. This would be a major part of the continual improvement of the AIT.

5.2.2.2 Alternative Actions. (57) Learning by example is an important construct of the instructional process. The alternative tactics characteristics of SMARTTS provide tools to the instructor to rapidly generate alternative examples and their associated performance-related information, and to provide comparative summaries of those alternatives. Alternative actions, as used herein, is the same as alternative tactics except that it is applicable to any training application, not just tactics. Alternative tactics should be viewed, therefore, as a subset of alternative actions. Alternative actions is the generic terminology representing the concept of using the training device characteristics to generate multiple alternative sets of actions to assist in learning by example.

The alternative actions/alternative tactics capability on SMARTTS requires the entry of substantial setup parameters to generate the detailed information relevant in the complex tactical situation. It is recommended that a research program be undertaken to improve the instructor interface with alternative actions-type capabilities. This would require the identification of various ways of implementing alternative actions, and their evaluation from a human-interface and training standpoint. It is expected that substantial trade-offs do exist between the human interface considerations and the generation of information necessary from a training standpoint. The impact of these trade-offs are also likely to vary as a function of other aspects of the training situation. Since the alternative actions-type capability has such substantial potential for improving the effectiveness of training, it warrants the attention of an in-depth research program to achieve effective interface designs that will insure its use during the training process.

Several considerations for the alternative actions/instructor interface are:

a. Automatic selection of alternative actions for ownship and targets via a computer-based model of the tactical situation. This model would key on particular parameters in the situation as they develop to automatically recommend several ownship and/or target alternative tactical actions for investigation by the instructor and trainees; this model could also provide the major points of rationale for selection of the alternatives. Finally, the model would bring up the alternatives for investigation as the result of a single input command by the instructor.

b. Available alternative actions could be categorized for different segments of a tactical encounter. For example several fundamental TMA approaches are available (i.e., point-lead; lead-lag; point-lag). Within each of these alternative categories various subcategories are available. For example, in the lead-lag TMA approach tactic various ownship course changes and the times at which those changes are initiated are available. A repertoire of these alternatives relative to the actual actions chosen during the real-time exercise could be rapidly generated by the computer and presented to the instructor for selection. During the alternative tactics session, therefore, the instructor would select a set of alternative actions for investigation from the complete set generated and made available by the computer.

c. Alternative tactical actions could be predetermined for each exercise prior to its use, scripted (i.e., canned), and stored along with the basic exercise parameters. The instructor could then select alternative actions from the this predetermined set available with each exercise.

d. Various control/display characteristics are available for the instructor interface. SMARTTS currently requires the instructor to punch in the necessary ownship and target maneuver parameters for each leg of the alternative tactics session. It is expected that a more efficient human-engineered interface is possible through the use of other hardware and/or software presentation characteristics. Examples include: a joystick, mouse, or ball-and-track for positioning a cursor to the next

incremental position of ownship, allowing the computer to calculate the actual maneuever parameters; analog type of display presentation and control capabilities on the plasma entry device for selection of ownship or target actions.

5.2.2.3 Performance Indicators. (58) The performance indicators are key characteristics of training assistance technology, and the SMARTTS preprototype. Together with the tactical variables the performance indicators form the bulk of information that is provided to the trainees and the instructor via the information displays. A set of objective and subjective performance indicators have been developed for the SMARTTS preprototype, addressing basic submarine tactics training. This set is by no means comprehensive for basic submarine tactics training, much less for the entire scope of submarine tactics training. Rather, it is a representative set of PIs. A long-term research and development program should be initiated to investigate and develop PIs for tactics training. It is expected that the PIs will evolve over time as the tactical situation and training technology change, hence the need for continual development of PIs. Several issues are relevant to the research and development of PIs:

a. (59) Representative PIs should be validated with regard to their relevancy to the training process.

b. (60) The appropriateness of minimum performance standards with regard to the achievement of terminal training objectives should be investigated. These performance standards would relate to a particular level of performance with regard to one or more PIs.

c. (61) Both objective and subjective PIs need to be continually developed to keep pace with the ever changing tactical situations and needs. Information and feedback display formats should be developed together with the PIs so as to best convey the desired information. The instructor console interface characteristics should also be developed in conjunction with the subjective PIs to facilitate their entry by the instructor.

d. (62) Individual PIs and team-level PIs should be developed. The team-level PIs should represent summary performance by the complete team or subteam elements. They should address not only the tactical outcome of particular segments of the exercise, but also relevant team-related characteristics.

e. (63) Summary PIs should be developed for the purpose of evaluating team performance with regard to meeting terminal training objectives. The PIs developed in the preprototype SMARTTS were designed to provide training-related information. This should be the purpose of the majority of PIs. In addition, however, the need does exist for PIs with which to evaluate training progress, relative team performance, and tactical readiness. The TEF metric developed by SUBLANT is an example of a summary PI. This type of information is necessary for the various research and development efforts (i.e., to evaluate the effectiveness of various TAT capabilities).

f. (64) An analysis should be undertaken to identify performance criteria from all phases of tactics training, for which the development of appropriate PIs can be undertaken.

This research and development program should seek to: (a) develop applied performance indicators for use in training, and (b) develop manual tools for use by the instructor and automated tools to collect the necessary information and generate the appropriate indicators. The submarine tactical training situation is extremely complex and does not readily lend itself to the assessment of performance, particularly at the team-level. As a result, the more encompassing summary performance indicators tend to be subjective. The research and development program should, therefore, also seek to develop tools for use by instructors in the subjective evaluation process.

A survey should be conducted of the Fleet, SCST sites, and the PXO/PCO training program to identify performance criteria leading to the development of performance indicators. An SCST site survey was recommended above with regard to the 21A41A site work (Section 5.2.1.5, #50). It may be appropriate to expand that survey to address candidate criteria and performance indicators, and also expand it to the Fleet and PXO/PCO training programs.

5.2.2.4 Information Presentation. (65) The SMARTTS information displays are the primary interface with the trainees and the instructor. Characteristics of the information display interface should have a tremendous impact on the effectiveness with which information is transmitted, and hence of the training process. The design of information displays today is largely an art form, and often relatively ineffective. Of the research that has been conducted, almost none has addressed display design to achieve an effective information transmission medium with regard to the training process. A wide range of issues, therefore, require investigation. These include:

a. (66) The training effectiveness of fundamentally different display dimensions (e.g., alphanumeric information versus graphic information) with regard to the training of specific skills and knowledge.

b. (67) The use of color.

c. (68) Unique display requirements pertaining to the trainee; unique display requirements pertaining to the instructor.

d. (69) The use of aural information either alone or in combination with visual information. The aural information dimension has been seldom used as a training aid, in comparison with the visual dimension. Several unique aspects are related to the aural dimension, however. The most obvious is that it presents additional information dimensions that can be used in parallel with visual information. For example, while the instructor is attending to the particular aspects of a problem away from the instructor's console he can be receiving status information and cues aurally. Although the instructor does typically receive aural information each day, little attention has been given to the various aspects of

presenting such information (e.g., timing, quantity, format, etc.). In those training situations where the instructor must interact heavily with one or more students, away from immediate access to visual information on an instructor's console, aural information provided to the instructor may be the most effective means of giving him cues and status information. Also, aural information may be an effective means of providing guidance and immediate feedback to trainees during a particular training exercise. For example, aural feedback or guidance information may be presented to a single individual without affecting other trainees in the team. With the existing capability of providing relatively good computer-generated voice synthesis at low-cost, aural information may be a means of providing automated assistance. Research should be conducted to determine the capabilities and limitations of aural information with regard to the various aspects of the training process. This research should address both the instructor (i.e., from a status and cue standpoint) and the student (i.e., from the standpoint of providing guidance during the training exercise, as well as for providing additional feedback information during the debriefing session -- for example, while the entire team is receiving visual information during the debrief individual operators may be receiving additional aural information tailored to their specific problem aspects). The research should address both manual and computer-generated automated aural information.

e. (70) The use of three-dimensional display representations for the three dimensional submarine environment. An aspect of substantial potential impact on training effectiveness is the use of three-dimensional display presentation techniques (e.g., object rotation; transparent objects) on a two-dimensional CRT display. Several aspects of the submarine tactical problem are heavily dependent on the three-dimensional environment, although they have traditionally been viewed as a two-dimensional problem due to equipment and conceptual limitations. Unfortunately, too often the operators themselves view the problem as two-dimensional due to display limitations; this must certainly have an adverse impact on operational effectiveness. Figures 16 and 17 address the target/firing point relationship and the weapon/target relationship, providing examples of a possible three-dimensional display format. During an approach and attack on a target, ownship seeks to maneuver to within weapon range, and at the greatest possible range consistent with his objectives launch the weapon. The weapon launch range is dependent upon the weapon's characteristics (e.g., speed, amount of fuel), target angle on the bow, environmental characteristics (e.g., existence or absence of a layer), and other factors. The probability of kill would depend upon the particular combination of factors at the time the weapon was launched. If a particular probability of kill was wanted (e.g., 60 percent) then a three-dimensional surface could be located around the target representing a complete set of points at which a 60 percent probability of kill could be achieved. This surface would be irregular and dependent upon the variety of ownship, weapon, target and environmental characteristics in the particular target situation. The SMARTTS preprototype provides a firing point which is a single point in space representing the desired culmination of the approach, and the point at which the weapon would be fired from ownship. This single point, although useful in the training context, is incomplete in that it implies that a single point in space is the desired firing position, whereas many firing points actually exist. The single firing point in the SMARTTS preprototype
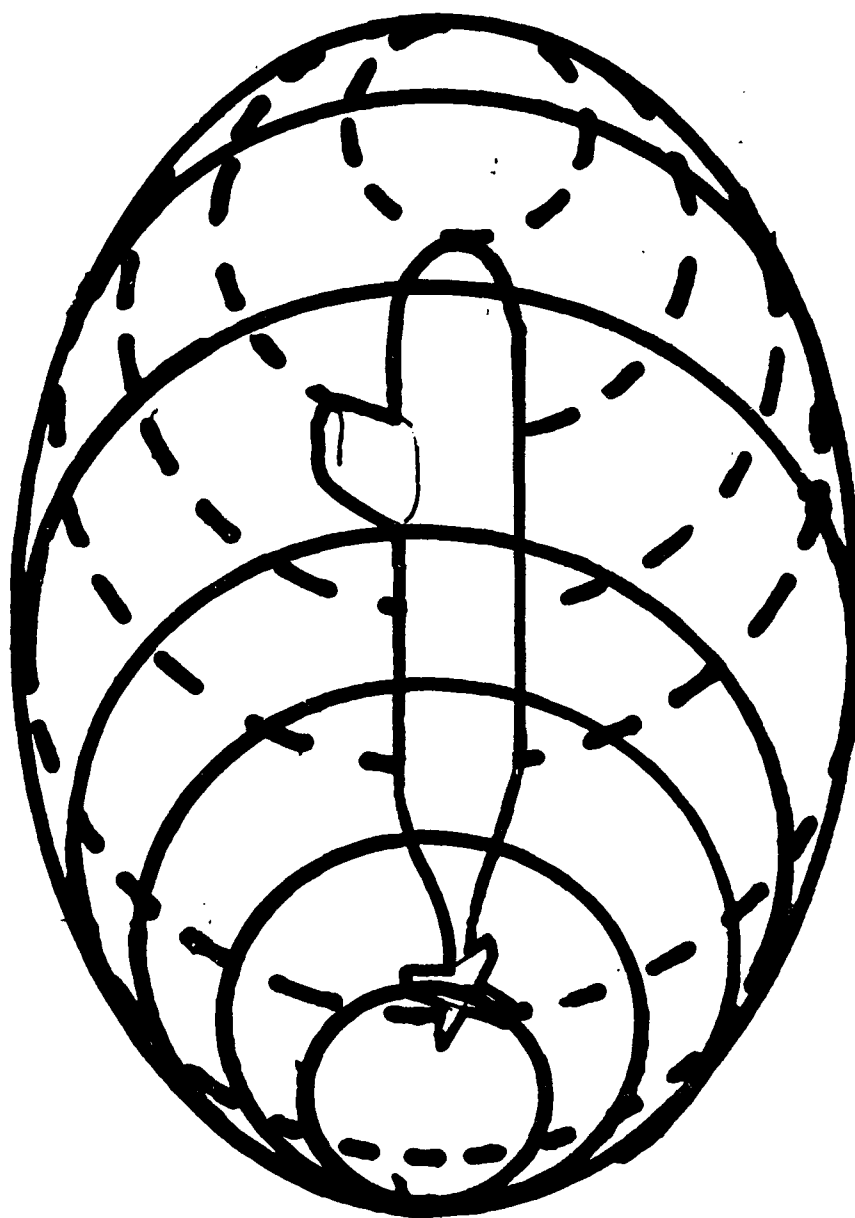
Figure 16. Conceptual example of three dimensional surface of equal hit probability firing points around target
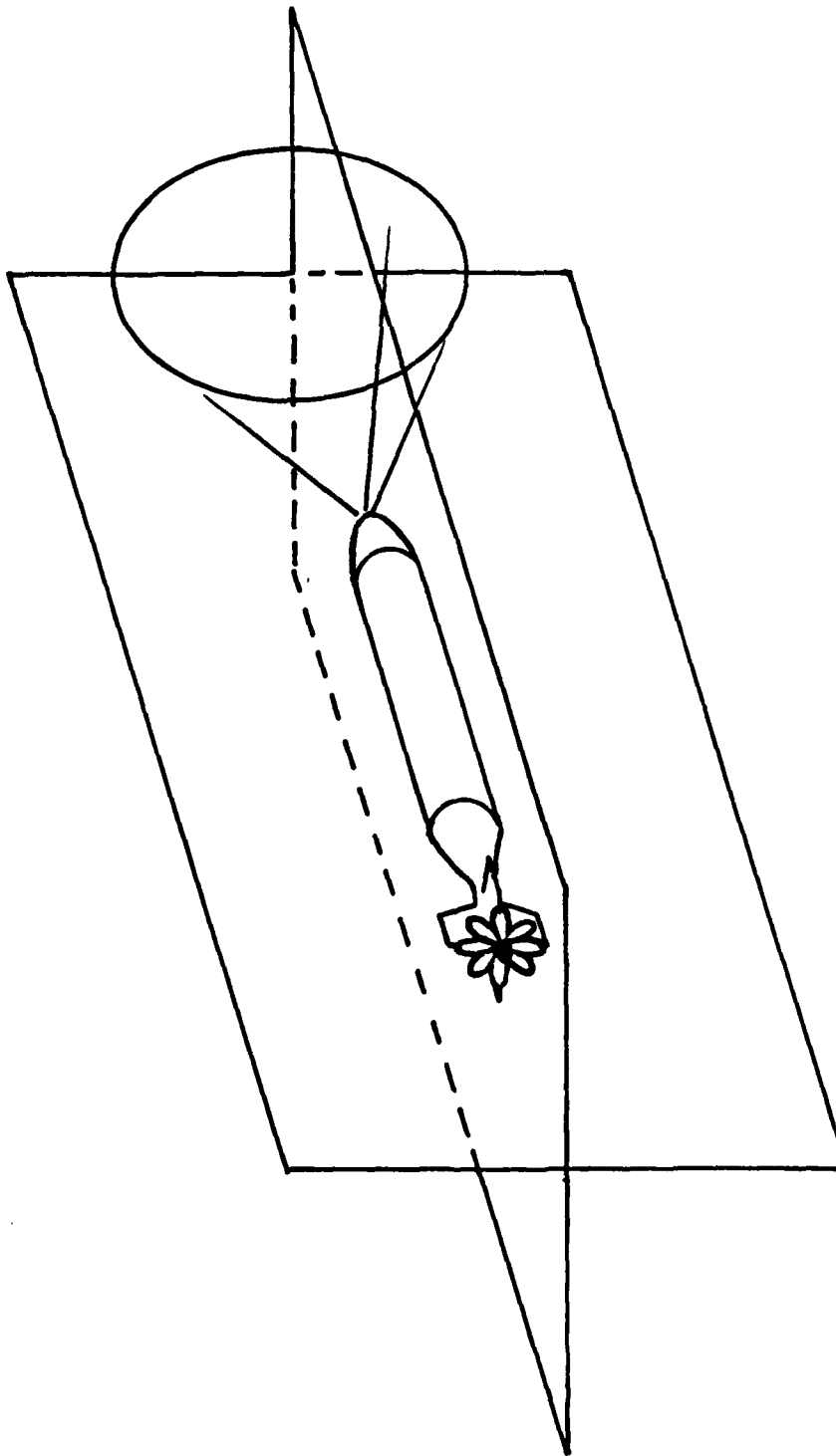
Figure 17. Conceptual example of three dimensional display illustrating weapon deployment

would be a single point on the surface of the three-dimensional firing point envelope surrounding the target. Figure 16 provides an illustration of what this type of envelope might look like. A display format of this type would appear to be useful in addressing approach tactics, weapon launch point, target characteristics impacting ownship tactics and weapon launch, and so on.

Weapon deployment is another three-dimensional problem that is relatively difficult to address in the current training context. Figure 17 illustrates a three-dimensional diagram of the torpedo and its acquisition cone. This type of diagram might be useful for illustrating the three-dimensional search and acquire characteristics of the torpedo in a manner similar to that discussed above with regard to the firing point.

f. (71) The use of motion on instructional displays. Motion has seldom been used on a display surface in naval tactics or training. Motion is an information dimension that has unique aspects with regard to human preception. It may facilitate, for example, the learning of skills to project an evolving situation out in time. For example, if coupled with the three-dimensional display suggested above regarding weapon deployment (Figure 17), the capability to have the torpedo go through three-dimensional search patterns in fast-time via presentation on a display may greatly aid the student in understanding the various search patterns of the weapon, and their capabilities and limitations with regard to various target types and target actions. Motion is used today on several SMARTTS displays as the situation evolves in real-time or fast-time. However, the motion on these displays is purely an artifact of their update rate to provide appropriate status information. Nevertheless, the motion of ownship and targets when run in a fast-time configuration does appear to provide a more effective mode of information presentation regarding the interaction between platform in the particular situation, as compared with showing the completed history tracks of ownship and the targets at completion of the exercise. It is expected that if motion were directly used to illustrate aspects of the problem, such as the torpedo search activities, the effectiveness of the training in these instances would substantially improve.

g. (72) Plasma-type touch entry instructor command sequences. The plasma entry device is a unique medium in that it provides information presentation, as well as accepts input commands. The discussions herein regarding the plasma entry device would pertain equally to other display surfaces that are touch sensitive. The plasma capability effected on the SMARTTS preprototype is considered to be the base level of plasma-related capability. English language text is used in place of acronym command sequence; the number of response options available to the instructor is controlled and related to each particular situation; information relevant to the particular input options available is controlled and presented; and the entire input sequence is logically structured and related to the particular subset that the instructor is dealing with at any time. These capabilities certainly improve the ease of interacting with the training device, as well as substantially improve the effectiveness of learning how to use the training device. The instructor's console becomes a training aid in itself due to the inherent capabilities of the plasma display/entry device. Two additional levels of increasing sophistication centered around the plasma

device have been previously suggested: (a) configuration of the information presentation formats and command entry actions tailored to instructor characteristics; and (b) use of artificial intelligence-related capabilities to improve the functioning of the instructor's console via the plasma-type interface. For example, the information presentation and command entry characteristics may be improved through the use of better display formats (e.g., a much greater use of graphics for information presentation and for command entry). The sequences of system operation may be improved as a result of a better understanding of the instructor tasks in using the system. Improvement in the instructor command sequence could be accomplished automatically by the machine itself. The machine can monitor the usage patterns by the instructor, and devise an optimum usage pattern minimizing the number of command steps. Research should be conducted, in conjunction with that recommended above pertaining to display formats, etc., to devise the principals of effective formatting and command sequence structures for the instructor's console. These should be centered around the touch-sensitive command entry surface.

The plasma-type touch entry surface facilitates operation since it provides information and accepts commands in a compatible format with the human instructor. The plasma-type entry device does not directly impact the types of processing functions that occur behind the interface, with the exception that it does enable the use of interface functions that are more amenable to the instructor operator since it is less constrained by the engineering mechanics of the interface. That is, when entering information via an alphanumeric keyboard the instructor is adapting to the rigid characteristics of the entry medium, in the form of learning appropriate acronyms, etc. With the plasma entry device, the instructor simply reads in English-like text and points to the selections. This can be further extended as noted immediately above by the use of graphical information and selection options, in further alignment with the human capabilities of the instructor operator (i.e., he typically can read English language text quite well, as well as point to things; also, presumably, visual graphical information is a more effective means of presentation and selection in certain instances). This facilitation of the direct human interface is likely to further enhance the interface with the computer system processing and the use of artificial intelligence-related processing functions, since it fosters a more symbiotic relationship between the instructor and the device. The characteristics that can be provided at this highest level of interface functioning are not readily known at this time. A training device manufacturer would be unlikely to provide many characteristics in this regard today. However, this should be the direction for research since it has a tremendous potential for improving the relationship between the instructor and the training device, and greatly enhancing the training process.

5.2.2.5 <u>Processing Support</u>. (73) Major underlying characteristics of SMARTTS center on its capabilities to process data, generating information such as the performance indicators, alternative tactics, and so on. Other information processing characteristics may be relevant in support of the training process. These include real-time processing characteristics to support the exercise development, conduct of training, and briefing

sessions, as well as the longitudinal analysis capabilities identified in the SMARTTS Type A specification. Research should be conducted to investigate the effectiveness of various support processes to enhance the conduct of training and to support the site management functions. Relevant issues include:

a. (74) An investigation should be initiated to identify potentially useful support processing characteristics. These would include characteristics to assist the instructor in monitoring and evaluating relevant exercise-related aspects during the real-time problem execution; in designing and evaluating exercise scenarios; in evaluating team and individual performance after completion of the exercise; and in generating and providing relevant feedback information to the students following completion of the exercise. The investigation should also address long-term analysis capabilities to support necessary longitudinal analysis functions (e.g., evaluation of training system effectiveness; tactical team readiness).

b. (75) The development of statistical analysis routines to combine and evaluate training performance-related data across multiple exercises. These routines should permit, for example, the investigation of particular tactical training and operational problems (e.g., maneuvering to a firing position) related to particular types of exercises (e.g., barrier patrol); the tactical performance of various teams across a variety of different types of tactical engagements; the training effectiveness improvement of teams as a function of the amount and/or type of training received; and the identification of individual team proficiencies and deficiencies on which to focus subsequent training emphasis. Specifications for the analysis routines would be identified in the above recommended investigation, with the actual routines developed under this particular task issue.

c. (76) The development of processing routines to support the instructor in assessing the input characteristics of particular combat teams. The input characteristics would be based on the prior performance of the respective teams in selected training exercises. These characteristics could be used in whole, or in part, to diagnostically evaluate a combat team's capabilities and limitations, and substantially aid the instructor in tailoring a training program to meet their specific needs.

d. (77) A standardized scenario structure should be developed for categorization of scenarios and their parts. This would enable the establishment of a data base across multiple scenarios and/or scenario parts for evaluation of training performance, and for the selection of appropriate exercises to meet particular training needs. Each training scenario, today, is considered as unique. However, it is suggested that only several basically different scenarios or scenario parts, in fact, exist in specific training applications (e.g., submarine tactics); many scenarios or scenario parts are suggested as being similar, perhaps differing only in minor aspects. The SMARTTS control group data collection effort developed a series of performance evaluation tools to assess different aspects of tactical team performance. These tools included categorization of different scenario parts, so as to enable comparison of performance across different scenarios. This may be a good starting point for development of the standardized scenario structure. Processing capabilities should be

developed to enable the instructor to index through scenarios identifying their relevant parts, selecting scenario parts to configure a complete exercise, and selecting scenarios to achieve particular training objectives.

e. (78) Processing characteristics should be developed to assist the instructor in the setting up and managing of the instructional process across multiple courses and student teams. In particular, these would be computer-managed instruction (CMI) capabilities.

f. (79) Processing characteristics, in addition to those currently on SMARTTS, should be developed for use by the instructor in actually conducting the training process. These may include real-time analysis routines to investigate different aspects of a particular exercise, to present multiple performance indicators and/or tactical variables, and to investigate a variety of alternative actions. The discussion/recommendation above concerning alternative tactics (Section 5.2.2.2, #57) would be relevant in this regard, as well as the development of new performance indicators (Section 5.2.2.3). The intention of this issue is to develop additional processing characteristics to analyze and present the performance-related information concerned with the prescenario and postscenario exercise briefings. It might include an on-the-spot analysis of a particular exercise with regard to overall performance indicators, comparison of performance in a particular scenario with the performance of other combat teams, and comparison of the performance of a particular combat team with their previous performance.

Minimal support processing characteristics have been included in the preprototype SMARTTS. These have been recognized in the type A SMARTTS specification as necessary for the conduct of effective training, both from the standpoint of the training process itself as well as from the larger management aspects. In many respects the development of processing support capabilities is not a research issue, but rather a developmental issue.

5.2.2.6   Instructor-Specific Characteristics.   (80)   Most of the characteristics included in the preprototype SMARTTS, and addressed in this research and development plan are intended to aid the instructor in conducting his functions. Many of these also pertain to the trainee in that they enable the instructor to generate guidance and/or feedback information in more effective formats for presentation to the trainees. Other characteristics are specifically directed at assisting the instructor in conducting his functions, and do not directly interface with the trainees. Those are included in this category. Several characteristics, in addition to those identified earlier, are recommended to be investigated. These include the following:

a. (81) The development of guidelines for instructor console design. It may be possible to develop an effective general purpose instructor's console to cover a large portion of training devices. This appears feasible due to the general purpose nature of many instructor/program operator consoles, which differ between devices only in the particular instructor interface information. A standardized general purpose instructor's console would have many advantages, in addition to cost benefits. The necessary

training of instructors, for example, would be minimized if they have had previous experience as an instructor, or had earlier experience in one form or another with an instructor's console. Considerable research effort could be placed into designing a general purpose instructor's console, the benefits of which would therefore translate into multiple training applications (i.e., the cost of research and development would be amortized across multiple training devices). This may become a reality due to the increasingly generalized nature of operational consoles in many areas of naval operations. It behooves the training community to lead the way in the design of a general purpose instructor's console, rather than have it forced upon them as a result of evolving operational systems. Hence, the need to initiate an instructor's console investigation effort.

   b. (82) An instructor interface language should be developed to facilitate the instructor's interaction with the training device, and greatly assist his using that device to perform his various functions (i.e., dealing with exercise design, control and monitoring of training, trainee briefing and so on). The typical instructor in military training systems has a good operational background (e.g., submarine operating experience for a submarine tactical instructor), although a limited instructional and computer background, particularly with regard to operating specific training devices. It is desirable to have a computer language developed to facilitate the instructor's interface with the training device. This interface language should permit the instructor to interact using somewhat standardized operational terminology, instructional terminology, and/or near-English terminology. It should be designed to accommodate those activities normally performed by the instructor when interfacing with the training device. With regard to exercise development, for example, this language should accept descriptive commands by the instructor in the form of the normal operational parameters (e.g., whereas the computer manipulates targets on an X, Y, Z grid, operational personnel often view the geographic situation in terms of range, bearing, and depth/elevation). Furthermore, the interface language should be structured to contain a large set of macro functions that readily translate the instructor's needs into exercise, performance indicator, cue, feedback display, etc., modifications. For example, the capability should be provided to enable the instructor to readily tailor feedback displays to particular exercises; that is, the instructor should have the capability to readily modify a particular display format to fit the needs of a particular exercise. This macro function should enable the instructor to rapidly provide the information necessary to configure the display in terms as close as possible to those operationally used, and then have the computer automatically configure the display. This might be accomplished using a digital interface drawing tablet, with appropriate parameter data readily accessible, and with standardized manipulation algorithms available. The instructor interface language would have the advantage of requiring minimal training on the part of the instructor to enable maximal use of the capabilities resident in the training device. The obvious advantage is more time available for the conduct of necessary training functions, and greater flexibility and capability to conduct those functions. It may, or may not, be feasible to have a standardized general purpose instructor's language, applicable across multiple platform types (e.g., air, surface, subsurface). Most instructor functions are generically similar across platform types, although the

specific data they deal with, the training methodologies used, and the device capabilities do tend to differ. Hence, it may be possible to have a generic instructor's language of which the bulk of processing capability is common across all training devices, but in which the specific interface language and perhaps some of the command characteristics need to be tailored to the particular training application.

c. (83) An exercise development simulation capability should be developed, and implemented on most training devices. A flexible high speed simulation capability is necessary to enable the instructor to review existing exercises, modify an exercise, or create a new exercise. Review, modification, or development of an exercise can be an extremely cumbersome and time consuming process. This is particularly the case where calculation of the developing time line scenario interaction is necessary to assure appropriate scenario events in support of the exercise objectives. The fast-time simulation should provide capabilities for the instructor to:

1. call up an existing exercise and run it in fast-time to any desired point, retrace steps, and so on;

2. investigate alternative actions from any desired time to any other desired time;

3. generate and display relevant performance indicators and situation parameters (e.g., target range) at the various times of the actual scenario and the alternatives under investigation;

4. modify any of the scenario parameters, enabling investigation of the tactical parameters and performance indicators at any subsequent point in time;

5. enter new performance indicator algorithms to be recorded and displayed during or subsequent to the exercise;

6. insert instructor cues to be automatically keyed at times during the exercise based on various aspects of the scenario parameters and/or time;

7. configure new feedback display formats for trainee briefings based on the training objectives, issues to be focused on, or parameters generated during this scenario, and so on;

8. develop new subjective performance monitoring input categories for observation entry by the instructor during the actual exercise;

9. setup all necessary scenario parameters for running the scenario on the training device;

10. permanently record the exercise in the exercise library for later review via this fast-time simulation capability and for actual running during a training exercise on the training device.

These capabilities are representative of those that should be included in an exercise development simulation capability. An investigation

should be made to determine which capabilities would be most helpful to the instructor, and the specific characteristics of their interface. The exercise development simulation should be a part of the instructor interface language, discussed above.

d. (84) Training devices have typically been poorly human factored from the instructor's standpoint. Many of the relevant human factors-related issues have been addressed elsewhere in this research and development plan. However, it is worthwhile to note that a distinct human factors research and development effort should be initiated, either under that heading or comprised of various individual parts such as broken out in this plan. Many of the SMARTTS capabilities would have been incorporated into earlier training devices if the instructor and trainee interfaces had been adequately looked at from a human factors standpoint.

e. (85) Instructional support material should be developed to assist the instructor in understanding and conducting an effective training process. This is an essential part of every training system, and often overlooked during the development and implementation of the expensive simulator-based hardware. An investigative effort should be undertaken to determine the characteristics of the essential instructional support material, with guidelines developed for its inclusion in the procurement of every training device/system. A variety of material should be available to the instructor as his primary resource for developing the training device exercise scenario. Most of this material would likely be in the form of handbooks, although some could be available in a computer data base. Ideally, a increasingly greater proportion of this necessary information would be incorporated into computer-based processing capabilities over time, to more directly assist the instructor. Information to be considered as a part of required instructional support material would include: (a) a complete set of tactical and behavioral training objectives, cross-referenced to exercises and operational situations (this may include cross-referencing to the standardized scenarios or scenario parts as suggested above); (b) a complete set of tactical reference information, such as naval weapons publication (NWP) series documents; (c) a set of guidelines regarding training methodologies, training device operations, and training exercise development; and (d) trainee input characteristics information, including previous trainee/team performance information, and training/tactical needs. The information related to trainee input characteristics could be available on a large information base assembled from previous training exercises of that particular individual or team, together with comparative data on the population of similar trainees, and so on. Guidelines should be developed for specifying the necessary material as a part of each training device/system.

f. (86) Artificial intelligence should be investigated as a capability for providing assistance to the instructor in conducting his many functions. It is expected that the artificial intelligence capabilities would be most applicable to the monitoring and control of the training exercise, as opposed to some of the other instructor functions. An investigative program should be initiated to develop and evaluate artificial intelligence characteristics for instructor support during the training exercise.

g. (87) Instructor console design features should be investigated. In addition to the investigation of a general purpose instructor's console, research should be conducted to evaluate and develop effective instructor console design features. These features may be appropriate to a particular training situation (e.g., submarine tactics) or generally applicable across a variety of situations. An example might be automatic selection of feedback displays keyed to each scenario exercise. Rather than the instructor having to select each display, perhaps the most applicable displays would be automatically selected by the computer, or have been previously designated to be brought up with each particular exercise.

h. (88) The effectiveness of alternative training methods should be investigated with regard to various trainee input characteristics, particular training problem areas (i.e., scenario types), and other aspects of the various training situations. This type of research should be continuous, since new training methods and aids are continuously being developed. The product of this research should be guidelines, or otherwise specific guidance information, addressing the applicability of alternative training methods in various training situations. Ideally, the guideline information would be specific to applied areas of training.

i. (89) The instructor has been shown to be one of the most important components of the training system (e.g., Hammell, Gynther, Grasso and Gaffney, 1981). Relatively little objective data is available on instructor characteristics and functioning. It is recommended, therefore, that an investigative program be initiated to determine relevant instructor characteristics, resulting in guidelines for instructor selection, preparation, and evaluation. The instructor should be investigated similar to any other element of the training system, with necessary information developed to guide in instructor selection and training to assure that he is an effective component of the training system. The instructor is probably the most overlooked element of the training system, the one that has probably the greatest impact on the effectiveness of the training system, and ultimately a high cost component in terms of availability and life-cycle cost.

5.2.2.7 Trainee Specific Characteristics. (90) Similar to that noted above for instructor-specific characteristics, many of the characteristics identified in other parts of this research and development plan pertain to the trainee interface. Several additional characteristics should be considered for investigation:

a. (91) A high level of trainee motivation is essential to an effective training process. Various ways of increasing trainee motivation (e.g., interest) should be investigated. These include the use of gaming techniques, interesting and informative information displays, innovative aids, alternative training methodologies, and so on. This investigative program should focus on ways of increasing trainee motivation, and not ways of developing more effective information presentation, etc.

b. (92) Student participation in the training process is considered essential. The SMARTTS preprototype provides an entry key for the student

to identify those times during the simulator exercise that he wishes to key on during the postproblem briefing. The effectiveness of this or other types of trainee entry devices/techniques should be investigated with regard to their impact on the effectiveness of training.

c. (93) Research should be conducted on the best ways to tailor training to individual students, subteams, or the complete team. There has been a variety of research conducted over the years on tailoring training to individuals (e.g., individual learning styles). Little of this research has addressed tailoring training to subteams or teams. Each of these should be looked at. In particular, methods of tailoring training on a cost/effectiveness basis within the available resources today should be investigated. For example, in a complex training situation involving a large team of individuals (e.g., the submarine combat team) it may be possible to configure scenarios that provide tailored training with regard to difficulty and presentation style simultaneously to meet the needs of each individual trainee, and in the team context. Automated assistance could be provided to the instructor to help in configuring a scenario to simultaneously meet the multiple needs of various trainees.

d. (94) The retention of training is an important issue in most training contexts, and one that has received relatively little attention. Considerable effort is spent in the retraining of individuals and teams in most aspects of military operations. The retraining intervals are usually chosen on the basis of many factors, with little objective data available related to the actual need for retraining. The retention issue has come up in many contexts, spanning from nuclear power plant operator to merchant marine deck officer to naval submarine commanding officer. It is recommended that an in-depth investigative program be initiated to thoroughly investigate the retention issue. This should be looked at with regard to the specific aspects of retention relevant to the requisite skills and knowledge, and the varying necessary retraining intervals for each. This data base could be extremely useful in determining the period of time between retraining sessions, as well as assist in appropriately focusing training during each retraining session. For example, it may be found that the higher level decisionmaking skills are retained well over time, while the more procedural equipment operating skills are retained poorly. The experience that operators have in particular equipment operating skills during the interval between the retraining sessions, however, may also differentially impact the level of skill retained. Hence, based on these factors, for example, the hypothetical retraining periods would primarily focus on those equipment operating skills that have received little experience during the intervening operational period, and in a much less frequent interval address the high level decisionmaking skills and those equipment operating skills that receive considerable use. The thrust of this research program should be to develop guidelines from which the retraining policies could be developed with regard to each specific application.

e. (95) The effectiveness of alternative display characteristics for effectively conveying information to trainees during various phases of the training process should be investigated. This issue would likely be

investigated with regard to the information presentation area noted above (Section 5.2.2.4).

5.2.2.8 <u>Training System Management.</u> (96) Training system management is one of the three major areas identified as requiring SMARTTS-type TAT characteristics; the other two are the instructor interface and the trainee interface. Training system management includes characteristics to support the development and maintenance of an appropriate training structure (e.g., setup and conduct of multiple training courses), intersite coordination, (i.e., including exchange of training performance data, training exercise designs, training material, and so on), and intrasite coordination. In addition, training system management includes the responsiveness of the training facility to the operational needs (e.g., interfacing with type commanders, etc.). The majority of capabilities necessary to support training system management are related to processing support/longitudinal analysis capabilities. The research issue to be addressed under training system management is the identification of characteristics necessary to support this major area of training system functioning. This should be an investigation to determine the proper management role to be conducted within the training system, including identification of the management functions, interfaces, and so on. The system characteristics necessary to support management would likely overlap considerably with those identified for processing support (Section 5.2.2.5). Hence, this research area and the processing support research area would likely coincide after the requirements are identified.

5.2.2.9 <u>Training Assistance Technology Guidelines.</u> (97) The preprototype SMARTTS is the initial implementation of training assistance technology. Its evaluation will provide information relevant to the evaluation of training assistance technology as a major element of the training system, along with evaluation of the specific aspects of TAT incorporated into SMARTTS. TAT and SMARTTS have evolved from and extensive analysis the training system and the training device, resulting in a series of recommendations pertaining to characteristics that should be added to many training systems. A major reason why TAT capabilities have not been traditionally included in the training system is the lack of guidance information suggesting their need and effectiveness in the training process, and identifying characteristics appropriate to various aspects of the training situation. Guidelines should be developed for the inclusion of TAT characteristics in virtually all training devices, with the type and extent of characteristics tailored to the various factors pertinent to each training device-system. The guidelines should address the following:

a. A comprehensive list of TAT characteristics should be developed. This list should identify each characteristic (e.g., objective PI's; subjective PI's; information displays), identify alternative types and/or levels of each characteristic, and provide examples of appropriate and successful application of each characteristic. Information should be provided in the guidelines explaining the characteristic, its purpose in training, and its typical use. This list would be similar to a shopping list that could be used in a check-off fashion regarding any particular

training device/system and training application to achieve a quick identification of the potentially useful TAT characteristics.

b. In-depth explanatory information should be provided regarding each TAT characteristic. This information should address the range of design for each characteristic, the range of cost for development, the capabilities and limitations of each regarding the training process, and those factors impacting the need for each TAT characteristic. This type of information would provide general guidance from which the appropriateness of a particular TAT characteristic for any specific training application could be determined.

c. Suggested design methodologies and their inherent steps should be recommended for determination of the appropriate TAT characteristics. The instructional systems development (ISD) process is an example of this type of methodology to be incorporated into the guidelines.

d. The guidelines should address the government's preparation of requests for proposals, military characteristics, etc. That is, they should provide guidance information relevant to the specification of necessary TAT characteristics. Furthermore, the guidelines should also address the actual design of the training device/system from the contractors standpoint. That is, they should provide guidance information relevant to the development of specific design characteristics regarding TAT in response to the requirements.

e. The process of incorporating TAT characteristics involves identifying the need for specific generic characteristics (e.g., performance indicators, feedback displays), and tailoring the specific interfaces to the particular needs surrounding each training situation.

f. Guideline information could be developed in the form of data item description documents.

The TAT guidelines should essentially be a handbook to be used by individuals to specify characteristics of the training device/system, and to assist in the design of the training device/system. They should be written generically, with specific applied examples. They should provide information which would assist the designer in identifying the specific TAT characteristics and determining their particular design.

5.2.3 OTHER AREAS. The above two major areas recommended in this research and development plan, 21A41A site work and TAT research and development, address the predominent issues directly stemming from SMARTTS and relevant to further investigation. Several additional research and development issues may be included under the rubric of training assistance technology, although not directly impacted by SMARTTS. These are very briefly identified in this section, since they should definitely be included in a research and development program investigating training assistance technology.

5.2.3.1 Gaming. (98) Single and multiple person games should be investigated and incorporated into the training subsystem of training devices. The AIT in SMARTTS enables it to be used in a gaming context, if so desired. Considerable research into gaming does exist which goes well beyond the AIT free-play context. The appropriate gaming techniques should be brought into the training situation, particularly at the level of individual training. The level of gaming can encompass a broad range, from very simplistic rapid games to the more complex tactical engagement games. A gaming capability could be one additional element added to SMARTTS that would further enhance its value as an individual training device. The investigative effort into gaming should seek to evaluate its effectiveness at various levels of training, determine the more effective dimensions of games that should be incorporated into training situations, and identify those aspects of the training situation amenable to the use of gaming. It is expected that gaming-based trainers will form a substantial segment of the overall training system in the near future. Unfortunately, although considerable research has been accomplished concerning gaming, relatively little of it has addressed the issues regarding training effectiveness and gaming.

5.2.3.2 Training Methodologies. (99) A wide variety of training methodologies currently exist and are in practice. These stem from classical methods, such as the use of immediate feedback, to contemporary methods that depend heavily on automated training aids (e.g., computer-assisted instruction). Most training methods in applied practice in the military environment seem to challenge the student, and place him in a trial and error learning situation; feedback is typically provided concentrating on the student's errors. Although this general set of methods is effective for a considerable portion of training, other methods are available which are likely to be substantially more cost-effective for many areas of training. Although considerable research does exist regarding a variety of training methods, the findings have not been adequately transfused into the applied training environment. Research is necessary to investigate alternative training methods in applied training settings. For example, certain methods may be most appropriate to high level officer tactics training (e.g., delayed feedback positive guidance). Very different training methods may be appropriate to very basic level operator training (e.g., immediate feedback). Ideally, guidelines would be developed as a result of this investigative program to assist in the design of the complete training system, from the standpoint of determining the appropriate training methods to be used during each stage of the training process, as a part of the training system.

5.2.3.3 Training Effectiveness Measurement and Evaluation. (100) The measurement and evaluation of training effectiveness should be an ongoing practice for every training system. The evaluation should begin at the design stage of the particular training system, follow through the development and implementation stage, and continue for as long as the training system is in operation and can be cost/effectively modified. The intent of this evaluation should be to insure (a) that appropriate TAT and other necessary characteristics are included in the design and adequately

developed; (b) to empirically verify the effectiveness of the various design characteristics with regard to modification of that particular training system and future training system designs; and (c) to continually upgrade the effectiveness of the particular training system while in use. Training effectiveness measurement and evaluation is occasionally conducted, usually from a purely empirical research standpoint. Seldom, if ever, is the training system design evaluated from the standpoint of its potential training effectiveness. As the hardware and software characteristics are evaluated at various stages during the design and development process with regard to their meeting design goals, so should the training-related characteristics of the training system be evaluated with regard to their meeting training effectiveness goals. SMARTTS developed an initial cut at this type of a process in terms of the training system evaluation test (TSET) which was conducted at the same time as the factory acceptance test. The TSET was an initial cut in that it took place long after the system was designed, and sought to develop an approach to the evaluation of potential training effectiveness. Its primary purpose was to identify the myriad of issues surrounding the evaluation of training effectiveness during the design process, and suggest alternative means for that type of evaluation. An effort should be initiated to develop requirements for the training effectiveness evaluation at various stages during the design and development process of the training system. The research area briefly discussed above concerning TAT guidelines (Section 5.2.2.9) would be an important source of information for this evaluation instrument.

The effectiveness of each training system after it is installed should be evaluated using objective data where possible. The intent should be to verify the effectiveness of the particular design, and identify strong and weak characteristics for consideration in future designs. This evaluation could be accomplished in a variety of ways including evaluation on the device itself and via transfer of training investigation. Evaluation procedures and tools should be developed to provide a generic framework for facilitating the evaluation of each training device. This developmental program would have to devise guidelines for the specification of specific performance measures, data collection tools, data collection and analysis procedures, evaluation procedures, and summary conclusion formats for feedback to the general training system design community. The intent should be to develop generic tools that can be adapted to the specific needs of particular applications (e.g., funding availability, time/schedule constraints, complexity of training, etc.).

Every time a training exercise is run on a sophisticated simulator-based training device considerable performance data is generated, and usually lost. These data, particularly when supported by SMARTTS-type TAT characteristics, can be retrieved and used as a major source of information to continually evaluate the effectiveness of the training system. This evaluation should focus on the variety of aspects of the training system, including the training methods, simulation fidelity, the TAT capabilities, the instructor, and so on. The evaluation should be aimed at identifying those aspects of the training system that could be improved, and recommend improvements. If the tools are adequately developed for the initial effectiveness evaluation of the training system they could be also used for the continual evaluation.
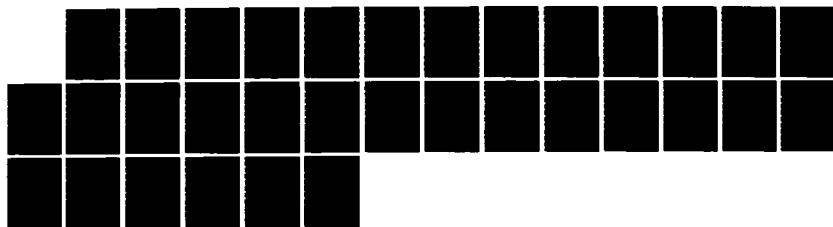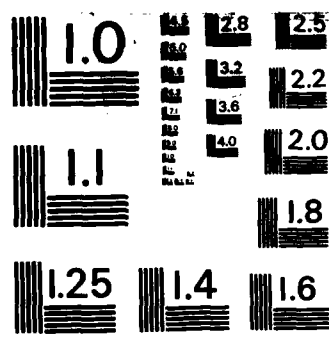
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The development of evaluation instruments and procedures is a necessary requirement to assure the effective design and evolution of training systems. This has been generally overlooked from the standpoint of day-to-day applied training operations, and usually reserved for occasional laboratory investigation. As with any complex system, it is necessary to have a constant source of information feedback regarding performance to assure that the system functions properly, and to evolve its capabilities as the training needs change and as new methods become available.

5.2.3.4 Embedded/Organic Training. (101) Embedded/organic training is likely to become the predominant context in which training is provided to individuals and teams in complex systems. This may hold true for both at-sea training as well as shore-based training. Modern computer technology allows the integration of training capabilities within operational systems to take advantage of available over time at sea for training. Furthermore, the future weapon systems are becoming increasingly complex and expensive, requiring a large number of operators. The expense of placing operational system simulators in shore-based facilities will decrease the number of such facilities. Hence, a greater portion of training is likely to shift to the at-sea environment. Furthermore, shore-based training facilities are likely to rely heavily upon the operational system itself; when an embedded training capability exists, it is likely that the shore-based facility will simply use that capability in place of other unique training capabilities. Hence, the design of the embedded/organic training system that will be integrated into future weapon systems is likely to become the predominent future training systems.

Although TAT capabilities are extremely important for the shore-based training systems, as has been demonstrated in several experiments, they are even more important for embedded/organic training systems. The shore-based facilities are devoted solely to training, with a full-time instructional staff, and other support capabilities. Conversely, the embedded/organic training system is merely a minor part of the complex weapon system. Furthermore, full-time instructional personnel do not normally exist in the at-sea training situation. Nor is the focus of that operational system primarily on training. Hence, the general at-sea environment for embedded/organic training will be much less conducive to the conduct of effective training than are the existing shore-based facilities. The need for TAT characteristics, therefore, is extremely important.

The embedded/organic training environment requires TAT characteristics to be directed at the individual trainee so as to assist him in directing his own training, generating his own feedback information from the system, evaluating his own progress, and so on. This would also be true of subteams and teams. The need for automated performance indicators and capable feedback displays becomes extremely important, since these will become the primary means by which the essential element of feedback is provided to the trainees. It is expected that the TAT capabilities required in embedded/organic training are much more critical then those required in shore-based training.

An investigative effort should be initiated to determine the TAT capabilities necessary to support embedded/organic training, across the various platforms in which such training will be implemented. Empirical investigations should follow on prototype units to investigate cornerstone capabilities of TAT in this environment. Guidelines should then be developed to provide necessary information to assist the designers/developers of embedded/organic training, and eventually appropriate guidelines and other training materials should be developed to support the users in conducting an effective training process. The general approach should be to automate as many of the TAT capabilities as possible (e.g., trainee guidance information). Several of the characteristics noted in this research and development plan would likely have a greater need for incorporation into embedded/organic training than into shore-based training (e.g., gaming models, such as those based on the AIT). The concepts of TAT are similar for embedded/organic training as they are for shore-based training such as SMARTTS. The particular TAT capabilities required most, and their specific characteristics, are however expected to differ in the embedded/organic situation. embedded/organic training is rapidly becoming a reality, and should pose a major training problem for the fleet. TAT capabilities are essential to insure effective training. Unfortunately, the research data is minimal in this area.

## 5.3 RESEARCH AND DEVELOPMENT PLAN SUMMARY

This research and development plan addresses the three major work areas of 21A41A site work, TAT research and development, and other areas of research and development. The purpose of the plan is to identify the major research and development issues relevant to training assistance technology (TAT), and the SMARTTS implementation of TAT. The plan seeks to address the complete range of relevant research and development issues, summarizing the status of each. Those issues pertaining to the 21A41A site work are addressed at the very detailed level, since recommendations can be made regarding specific aspects of the SMARTTS preprototype. Other more general issues are also addressed regarding the site work. The issues addressed under TAT research and development are typically done so at a broader level, since they are not necessarily in reference to a particular installation or device but rather with regard to generic TAT. Nevertheless, specific aspects are addressed regarding several of the issues as appropriate. The research issues addressed under the "other areas" category are done so briefly, since these are broad issues relevant to TAT, but not necessarily a direct part of TAT. The intention with regard to "other areas" has been to identify the major issues, and to provide some insight regarding each. Obviously, a myriad of specific issues pertain to each of these.

A broad range of research and development issues have been identified, clearly substantially more than can be accomplished over a reasonable period of time. Several of these issues pertain to the establishment of long-term programs, some of which will provide immediate and ongoing benefits while others are likely to provide only long-term benefits. Other issues are highly specific and are expected to provide immediate results. This plan addresses the broad range of issues, from which a next-level more detailed

research and development plan should be constructed. The next-level of plan should select those issues that appear to have good potential for investigation and/or accomplishment. To assist in the development of the next-level plan several of the major considerations likely to impact the development of this next iteration are addressed in Table 1. This table provides information estimates concerning each research issue, pertaining to the relevant dimensions identified earlier. An explanation of the categories and rationale pertaining to each subcategory in Table 1 is presented below.

a. Location -- Operational training device site and/or laboratory. The laboratory should be viewed as the location to perform most initial research, identifying those candidate issues/characteristics for which good evidence suggests will substantially impact training cost/effectiveness. The laboratory should generate the concepts, perform initial evaluation of them, and act as a screening process to identify those that have the greatest potential to improve the training process. Generally, this would include all basic research and much applied research. The site should be used to evaluate those issues/characteristics that have a high immediate potential for improving the cost/effectiveness of the training process, based on laboratory data and/or training analyst opinion. The site should also be used for providing modifications and/or upgrading of current TAT capabilities already implemented via SMARTTS. When the need for test and evaluation in the operational training system exists, particularly with regard to newly implemented characteristics, it should be conducted at a site.

The first two columns of Table 1 address the location, identifying that the particular issue should be addressed at the site or in the laboratory. Several issues are indicated for addressing at both the site and in the laboratory setting. Work regarding these issues may be appropriate in both work areas, depending upon the particular aspects being addressed and the phase of work.

b. Work Type -- Basic research, applied research, system modification, or system evolution.

1. Basic Research -- Research dealing with fundamental, generic training issues, not tied to a specific context.

2. Applied Research -- Research that is generally context-specific to a particular applied training environment.

3. System Modification -- Modification or refinement of existing TAT/SMARTTS capabilities on the 21A41A to improve their functioning.

4. System Evolution -- The development of new TAT capabilities with regard to the 21A41.

The basic and applied research types of work are either general, or may pertain to one or more different training devices, including the 21A41A SCST. The system modification and system evolution types of work both pertain to the 21A41A SCST. Hence, most of the "21A41A site work" coincides

with the last two respective Work Types, while much of the "TAT research and development" and "other areas" coincide with the first two types of work. Usually only one category of Work Type is indicated for most of the research and development issues, although several Work Types are indicated as appropriate on some of the issues.

c. Application -- Training process, or support. Those research and development issues that would directly affect conduct of the training process fall under the training process category (e.g., performance indicators, feedback displays). Those research issues that address training process development, system management, etc., do not have a direct impact on the conduct of the training process itself, and are indicated as support. Only four issues impact both training process and support functions.

The application category provides information relevant to the evaluation of the priority to be given to each research issue. However, a direct relationship between application and priority was not determined. Certain support processes, such as processing capabilities to assist in development of training exercises, may have a substantial impact on the effectiveness of the training process, while other capabilities which directly supporting the training process may have a minimal impact on the training effectiveness.

d. Priority -- Three levels of priority were allocated:

> (H) -- High priority
> (M) -- Medium priority
> (L) -- Low priority

The priority afforded the various research issues is extremely important since it determines those issues that will receive emphasis and funding, and hence those that will be addressed. Many factors must be considered in determining the priority of research and development issues, including the potential impact of results on improving the cost and/or effectiveness of training; the motivational value to either the instructor or the students; the cost of conducting the necessary research and development efforts, and their resulting implementation cost; and the climate (i.e., general acceptability within the Navy) for conducting particular research and development efforts. The priority assigned in Table 1 is an indication of the author's estimated priorities, based on these and other factors.

ε. Cost -- Several cost categories are provided as follows:

> (1) -- Less than $25K
> (2) -- $25K - $100K
> (3) -- $100K - $400K
> (4) -- $400K - $800K
> (5) -- Greater than $800K

These five cost categories were set up to provide a general indication of the cost magnitude for each of the research and development issues. Obviously, many factors will affect the actual cost of conducting

work regarding any of the research and development issues, which can certainly change the cost categories as estimated herein. The estimate of cost provided in Table 1 was independently determined for each research and development issue. If several issues are combined into a single program, the cost may change considerably and be considerably different than the sum of costs, either up or down. Furthermore, the scope and depth of work to be accomplished regarding each research issue can substantially change its cost either up or down. Hence, the cost estimates are provided only to give a ball-park idea of the relative magnitude of the various research and development efforts.

Usually, a single cost estimate is provided. For several issues, a range of costs is indicated (e.g., 1-3 indicating the cost can vary substantially over that range depending upon the specific factors associated with the particular work effort). The cost indicated is generally that estimated to adequately address the research and development issue within the scope intended in this research and development plan. For those issues that will require a long-term program, usually indicated in the comments column, the costs are indicative of a one year effort; obviously, a multiyear program will have costs that typically vary substantially from year to year, such as initially low cost during the early analysis phase with substantially higher cost during the later applied developmental phases. Hence, the cost estimate in these cases would represent an average level of effort for any given year during that program.

Several research and development issues for which the cost was indicated in the lowest category (i.e., 1) may cost substantially less than the upper $25K limit of that category. This is particularly true for several of the issues under 21A41A site work, especially if several were to be accomplished simultaneously. For example, if five or six recommended modifications were to be accomplished, with each of these falling in the #1 cost category, the cost may be substantially less than totaling the $25K value for each issue. Similarly, cost reductions would generally occur if multiple issues were to be investigated in a single program. This is due to the existence of many administrative and logistics cost items that would not change substantially if multiple efforts were to be conducted.

TABLE 1.  RECOMMENDATIONS REGARDING THE RESEARCH AND DEVELOPMENT ISSUES
(Refer to text for an explanation of each)

| WORK AREA | LOCATION | | WORK TYPE | | | | APPLICATION | | PRIORITY+ | CUST++ | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site Work | Lab | Basic Research | Applied Research | System Modification | System Evolution | Training Process | Support | | | |
| **21A41A Site Work** | | | | | | | | | | | |
| (1)* Preprototype Test and Evaluation | x | | | x | | | | x | H | 3 | All issues under site work are short-term |
| **Refine SMARTTS** | | | | | | | | | | | |
| (2) Cursor Control | x | x | | | x | | x | | M | 1 | |
| (3) Visual/Audible Plasma Command | x | x | | | x | | x | | L | 2 | |
| (4) Plasma Control Sequence | x | | | x | x | | x | | H | 1 | |
| (5) Plasma/Scaling Control | x | | | | x | | x | | H | 2 | |
| (6) Command Time Delay | x | | | | x | | x | | H | 1 | |
| (7) Target Identification | x | | | | x | | x | | M | 2 | |
| (8) Alternative Tactics Interface | x | | | x | x | | x | | H | | |
| (9) Automatic Own Ship Alternative | x | x | | | x | | x | | M | 1 | |
| (10) Use of Color | x | x | | x | x | | x | | L | 1-2 | |
| (11) Automatic Target Format Selection | x | x | | | x | | x | | M | 1 | |
| (12) Assign Own Ship | x | x | | | x | | x | | M | 1 | |
| (13) Plasma Hardcopy Switch | x | x | | | x | | | x | L | 1 | |
| (14) Subjective PI Entry | x | | | | | x | x | | L | | |
| (15) CRILS/CRALS Reference Point | x | | | | x | | x | | H | 1 | |
| **Add TAT Capabilities** | | | | | | | | | | | |
| (16) PI Modification Software | x | | | x | | x | x | x | M | 2 | |
| (17) New PI's | x | | | | | x | x | | H | 1-3 | |
| (18) Tactical Effectiveness Factor | x | | | | | x | x | | H | 1 | |
| (19) Time Frequency Plot | x | | | | x | | x | | H | 1 | |

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TABLE 1. RECOMMENDATIONS REGARDING THE RESEARCH AND DEVELOPMENT ISSUES (CONTINUED)
(Refer to text for an explanation of each)

| WORK AREA | LOCATION | | WORK TYPE | | | APPLICATION | | | PRIORITY+ | COST++ | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site Work | Lab | Basic Research | Applied Research | System Modification | System Evolution | Training Process | Support | | | |
| **21A41A Site Work** | | | | | | | | | | | |
| (22) Geoplot Feedback Display Mod | X | | | | | X | X | | H | 1-2 | |
| (23) Multiple LOS | X | | | | | X | X | | H | 1-2 | |
| (24) Designate Own Ship | X | | | | | X | X | | M | 2-3 | |
| (25) Weapon-Target LOS | X | | | | | X | X | | M | 1 | |
| (26) Time Range Plot | X | | | | | X | X | | H | 1 | |
| (27) AN/BQQ-5 SNR Plot | X | | | | | X | X | | M | 1 | |
| (28) Symbology Expansion | X | | | | | X | X | | L | 2-3 | |
| (29) 3-D Torpedo Feedback | | X | | X | | X | X | | M | 2 | |
| (30) Alternative Tactics-Depth | X | | | | | X | X | | M | 2-3 | |
| (31) Alternative Tactics Interface | | X | | X | | X | X | | H | 2 | |
| (32) Periscope Information | X | | | | | X | X | | L | 1-2 | |
| (33) Periscope PI's/Feedback | X | | | | | X | X | | M | 2 | |
| (34) Individual Operator PI's | X | | | X | | X | X | | M | 2-3 | |
| (35) Training Material Expansion | X | | | | | X | X | X | H | 1-3 | |
| (36) New Tactical Variables | X | | | | | X | X | | M | 1-2 | |
| (37) Approach Geoplot/LOS | X | | | | | X | X | | M | 1-2 | |
| (38) AIT Status Information Display Mod | X | | | | | X | X | | M | 2-3 | |
| (39) Additional IRC/CRC Display | X | | | | | X | X | | M | 2 | |
| (40) Additional Classroom Display | X | | | | | X | X | | L | 1 | |
| (41) Ecklund Range Display | X | | | | | X | X | | H | 1 | |
| (42) 21A41A Freeze | X | | | | | X | X | | H | 1-2 | |
| (43) Add Weapon Model | X | | | | | X | X | | M | 3 | |
| (44) Add Tomahawk/Harpoon | X | | | | | X | X | | H | | |

TABLE 1. RECOMMENDATIONS REGARDING THE RESEARCH AND DEVELOPMENT ISSUES (CONTINUED)
(Refer to text for an explanation of each)

| WORK AREA | LOCATION | | WORK TYPE | | | APPLICATION | | | PRIORITY+ | CUST++ | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site Work | Lab | Basic Research | Applied Research | System Modification | System Evolution | Training Process | Support | | | |
| **21A41A Site Work** | | | | | | | | | | | |
| (45) Expand Sonar Models | x | | | | | x | x | | M | 2-3 | |
| (46) Target Weapons | x | | | | | x | x | | L | 2 | |
| (47) Expand AIT | x | | | x | | x | x | | H | 3-4 | |
| (48) Add Decoys | x | | | | | x | x | | M | 1-2 | |
| (49) Test and Evaluate New TAT Concepts | x | | | x | | | | x | H | 2-3 per yr | |
| (50) SCST Site Survey | x | | | x | | | | x | H | 1-2 | |
| **TAT Research and Development** | | | | | | | | | | | |
| AIT | | | | | | | | | | | |
| (52) Development Plan | | x | | x | | | x | | H | 1 | May become on-going program |
| (53) Model Development | | x | | x | | | x | | M | 4 | |
| (54) Model Validation | x | x | | x | | | x | | M | 1-2 | May become on-going program |
| (55) AIT/Instructor Interface | x | x | | x | | x | x | | M | 2-3 | Should become on-going program |
| (56) Intelligence Collection re. AIT | | | | | | | | | | | |
| (57) Alternative Actions | | x | | x | | | x | | M | 2 | |
| (58) Performance Indicators | | x | | | | | x | | M | 3 | |

TABLE 1.  RECOMMENDATIONS REGARDING THE RESEARCH AND DEVELOPMENT ISSUES (CONTINUED)
(Refer to text for an explanation of each)

| WORK AREA | LOCATION | | WORK TYPE | | | | APPLICATION | | PRIORITY+ | COST++ | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TAT Research and Development | Site Work | Lab | Basic Research | Applied Research | System Modification | System Evolution | Training Process | Support | | | |
| (59) PI Validation | X | X | | X | | | X | | M | 3 | |
| (60) Performance Standards | X | X | | X | | | X | | M | 2 | Should become on-going program |
| (61) Objective/Subjective and Individual/Team | | X | X | X | | | X | | M | 3-4 | |
| (62) Summary PI's | | X | X | X | | | X | | M | 3 | |
| (63) Performance Criteria | X | X | | X | | | X | | H | 1-2 | |
| (64) Information Presentation | | | | | | | | | | | |
| (65) Training Effectiveness re. Display Dimensions | | X | X | | | | X | | M | 3 | |
| (66) Color | | X | X | | | | | | M | 2 | |
| (67) Trainee/Instructor Interface | X | X | X | X | | | X | | M | 2-3 | |
| (68) Aural Information | | X | X | | | | X | | L | 2-3 | Excellent potential for future improvement |
| (69) 3-D Displays | X | X | X | X | | | X | | M | 3-4 | |
| (70) Motion Information | | X | X | X | | | X | | L | 2-3 | |
| (71) Plasma-type Touch Entry | | X | X | X | | | X | | M | 3-5 | Long-term multi-year program |
| (72) Processing Support | | | | | | | | | | | |
| (73) Identify Support | | | | | | | | | | | |
| (74) Processing Needs | X | X | | X | | | | X | M | 2 | |
| (75) Statistical Analysis Routines | X | X | | X | | X | | X | H | 2-3 | |

TABLE 1. RECOMMENDATIONS REGARDING THE RESEARCH AND DEVELOPMENT ISSUES (CONTINUED)
(Refer to text for an explanation of each)

| TAT | Research and Development Area | LOCATION | | WORK TYPE | | | | APPLICATION | | PRIORITY+ | COST++ | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Site Work | Lab | Basic Research | Applied Research | System Modification | System Evolution | Training Process | Support | | | |
| (76) | Input Characteristics Assessment | X | X | | X | | | | X | L | 2-3 | |
| (77) | Standardized Scenario Structure | X | X | | X | | | | X | M | 2-3 | |
| (78) | Computer Managed Instruction | X | X | | X | | | | X | L | 2-3 | Long-term program |
| (79) | Real-time Processing Support | X | X | | X | | | X | | M | 2-3 | |
| (80) | Instructor-Specific Characteristics | | | | | | | | | | | |
| (81) | Instructor Console Design Guidelines | | X | | X | | | | X | H | 3 | |
| (82) | Instructor Interface Language | | X | | X | | | | X | H | 3-4 | |
| (83) | Exercise Development Capability | | X | | X | | | | X | M | 3-4 | This is a subset of the instructor interface language |
| (84) | Interface Human Factoring | | X | | X | | | X | X | H | 2-3 | |
| (85) | Instructional Support Material Characteristics | | X | | X | | | X | X | H | 2-3 | |
| (86) | Artificial Intelligence Support | | X | X | X | | | X | | M | 3 | Long-term program |
| (87) | Console Design Features | | X | X | X | | | X | | L | 3 | Long-term program |
| (88) | Alternative Training Methods | | X | X | X | | | X | | L | 2-3 | Long-term program |

TABLE 1. RECOMMENDATIONS REGARDING THE RESEARCH AND DEVELOPMENT ISSUES (CONTINUED)
(Refer to text for an explanation of each)

| WORK AREA | LOCATION | | WORK TYPE | | | | APPLICATION | | PRIORITY[+] | COST[++] | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site Work | Lab | Basic Research | Applied Research | System Modification | System Evolution | Training Process | Support | | | |
| **TAT Research and Development** | | | | | | | | | | | |
| (89) Instructor Characteristics | X | X | X | X | | | X | | H | 3 | |
| (90) Trainee-Specific Characteristics | | | | | | | | | | | |
| (91) Trainee Motivation | | X | X | X | | | X | | L | 2 | Long-term program |
| (92) Student Participation | | X | X | X | | | X | | L | 2-3 | Long-term program |
| (93) Tailoring of Training | X | X | X | X | | | X | | L | 2-3 | Long-term program |
| (94) Retention of Training | X | X | X | | | | X | | H | 2-3 | Long-term program |
| (95) Display Characteristics | | X | X | | | | | | M | 2-3 | |
| (96) Training System Management | | | | | | | | X | M | 3 | |
| (97) Training Assistance Technology Guidelines | | X | | X | | | X | X | H | 2-3 | |
| **Other Areas** | | | | | | | | | | | |
| (98) Gaming | | X | X | X | | | X | | H | 3-5 | Long-term program |
| (99) Training Methodologies | | X | X | X | | | X | | M | 2-4 | Long-term program |
| (100) Training Effectiveness Measurement and Evaluation | X | X | X | X | | | X | X | M | 2-4 | Long-term program |
| (101) Embedded/Organic Training | X | X | | X | | | X | X | H | 3-5 | Long-term program |

*Research and Development Issue numbers correlate with the descriptions in the text.
+ H = High, M = Medium; L = Low (see text for explanation)
++ 1 = Lowest Cost; 5 = Highest Cost (see text for the specific dollar rage of each category)

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APPENDIX A

INSTRUCTOR FUNCTIONS
(An excerpt taken from Hammell, 1982)


The major instructional functions supported by the preprototype SMARTTS are as follows:

a. exercise development

b. moniur and control of the training process

c. briefing (pre, freeze, post)

d. training system management

Monitor and control of the training process is the instructor function given the greatest recognition by training device builders (Figure A-1). When a training device is employed, the instructor must set up the exercise, control the device during the exercise (e.g., maneuvering targets), monitor the trainees' activities, and provide some amount of training during the exercise (e.g., guidance and feedback to the trainees). Capabilities, in one form or another, are provided on most training devices to enable set up and control of the exercise. Some capabilities are often provided to permit monitoring of trainee activities, and often some recording. Occasionally, capabilities are available for providing some training assistance, such as feedback. However, all too often the monitoring and control capabilities installed on a training device are designed from an engineering-control standpoint, rather than from an instructional process control viewpoint. Specific instructor tasks, A-L, are included in Figure A-2, along with generic training issues and considerations under each task. Also, the multiplicity of branching paths between tasks is also indicated to some extent by the A and B symbols. The information contained in Figure A-3 is a summary of the type of analysis information upon which the SMARTTS characteristics were based. For example, the instructor has a task to monitor the scenario (i.e., Task C). A consideration under that task, particularly in a complex system, is providing cues to the instructor regarding current and upcoming scenario events. Capabilities were developed in SMARTTS to provide cues and alerts to the instructor regarding various tactical actions on the part of the target, as well as when various performance indicators (e.g., probability of ownship counterdetection) went beyond preset standards. These capabilities, which are easily provided by the computer-controlled training device, reduce the instructor's scenario monitoring load, enabling him to devote a greater proportion of time to monitoring the trainees (i.e., Task H). Other examples are given later under Training Assistance Technology.

Briefing of the trainees (Figure A-4), in its various forms, is probably the most important function performed by the instructor. In this function the instructor has a direct interface with the trainees, and provides them with specific information to reinforce and/or modify their behavior. In a simulator-based training system briefings may be given prior to, during a pause in, and following completion of the session on the simulator (i.e.,

TRAINING SYSTEM

TRAINING OBJECTIVES ••• TRAINING DEVICE ••• TRAINING PROGRAM •••

SIMULATION SUBSYSTEM

INSTRUCTIONAL SUBSYSTEM

| INSTRUCTOR | TRAINEE | MANAGEMENT |

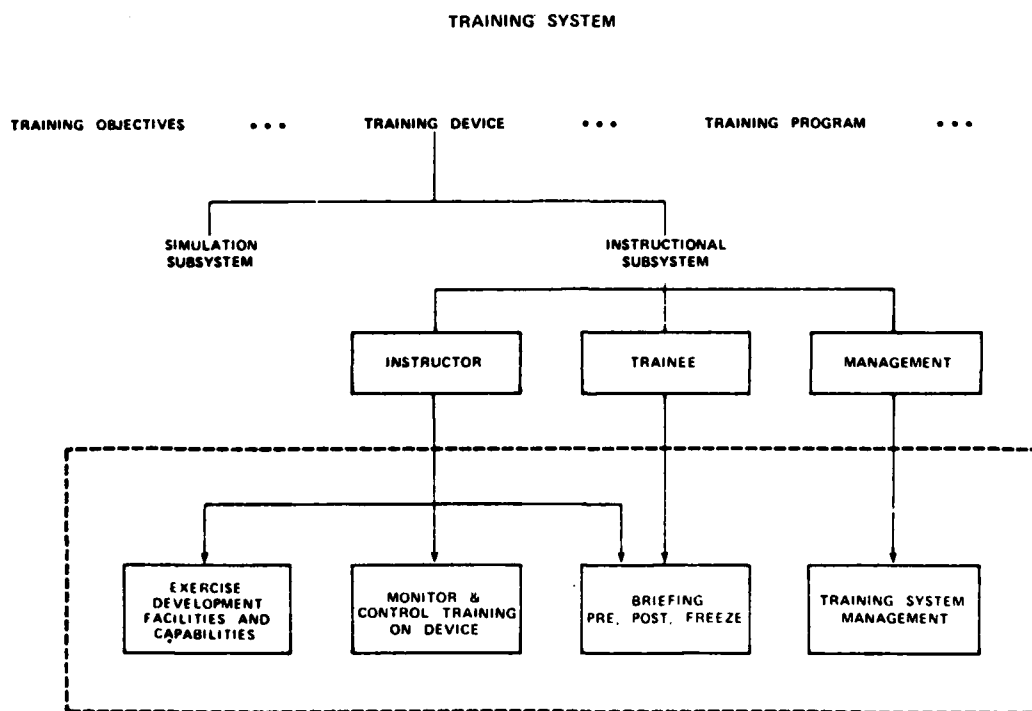| EXERCISE DEVELOPMENT FACILITIES AND CAPABILITIES | MONITOR & CONTROL TRAINING ON DEVICE | BRIEFING PRE. POST. FREEZE | TRAINING SYSTEM MANAGEMENT |

Figure A-1. Focus of instructional subsystem
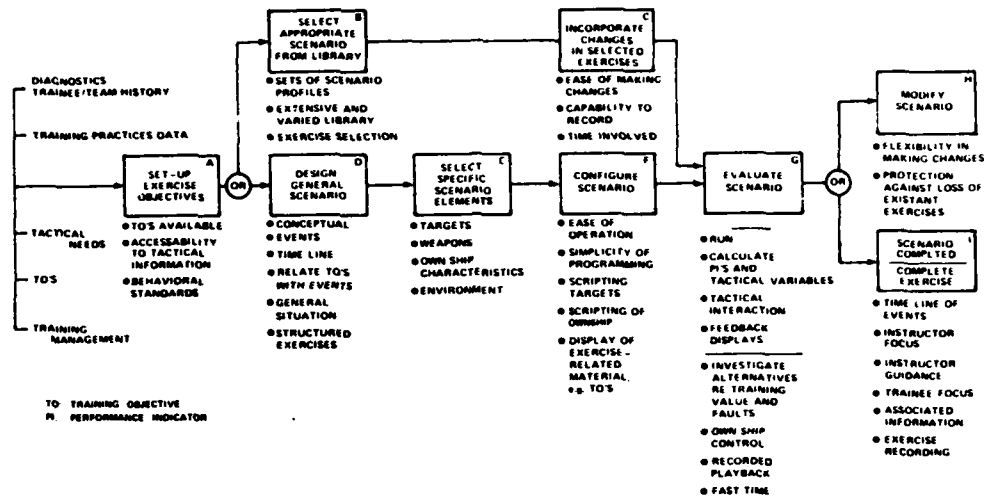
Figure A-2.  Exercise development



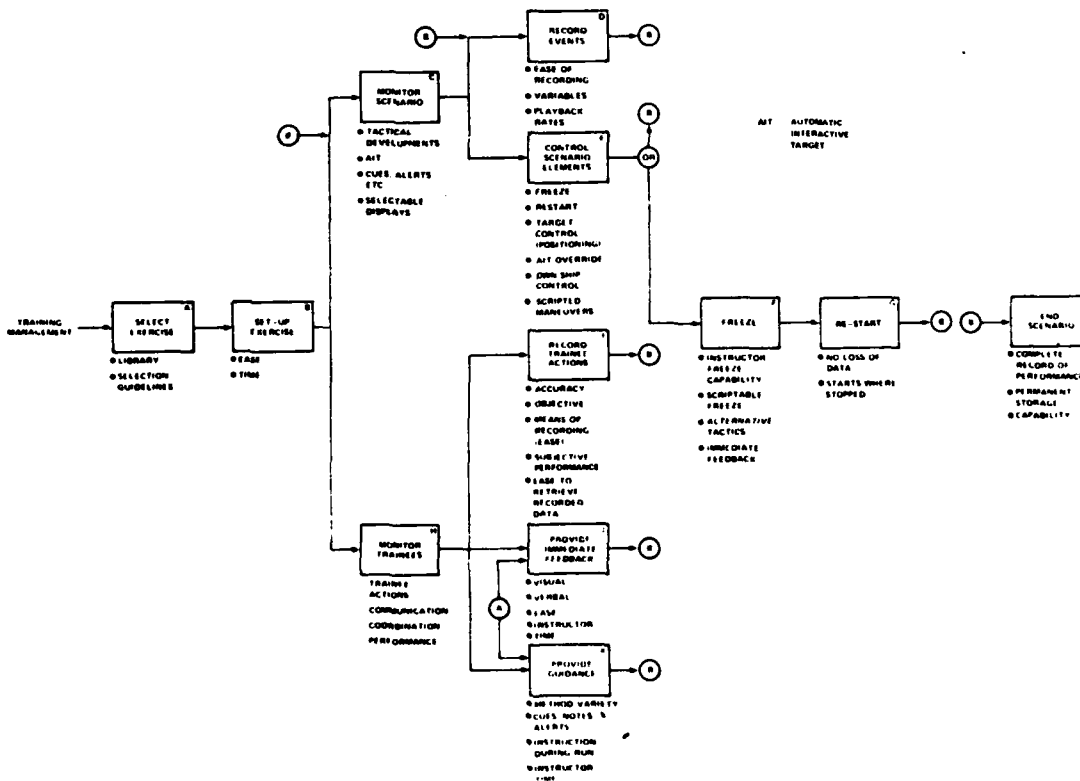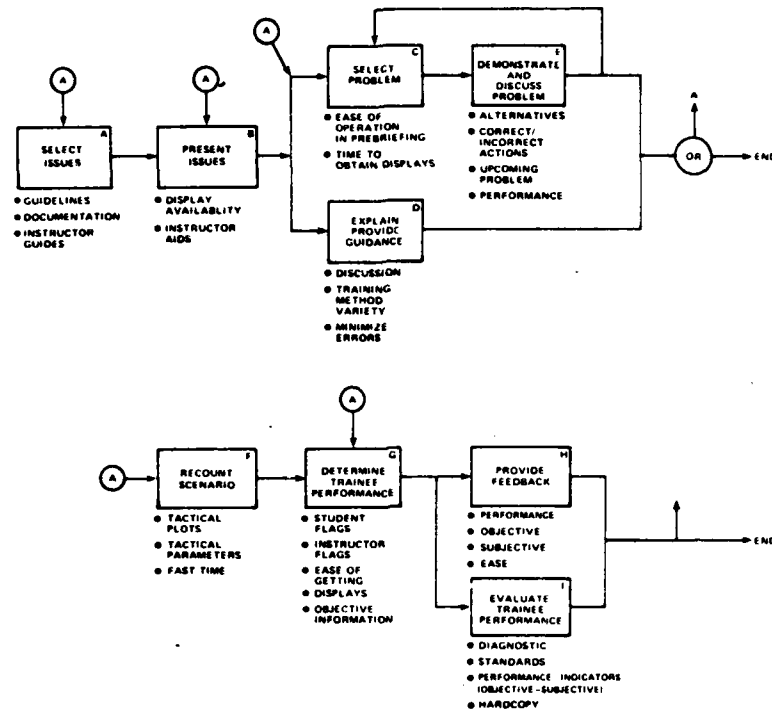Figure A-3.  Monitor and control training

Figure A-4.  Briefing (pre, freeze, post)
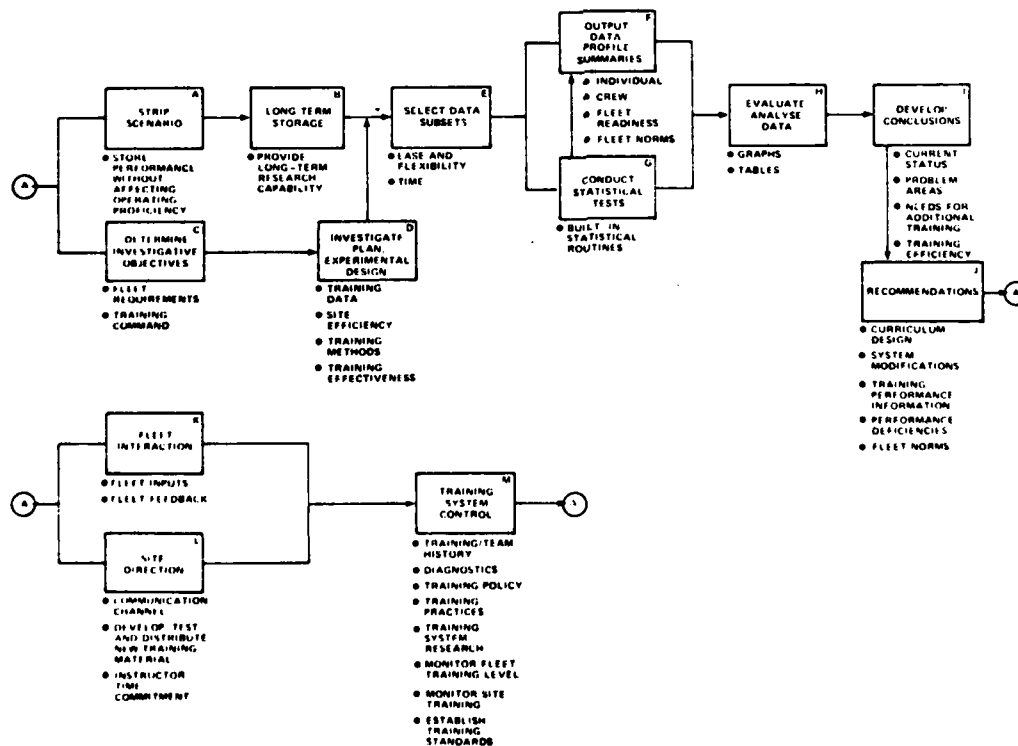


Figure A-5.  Training system management

pre, freeze, and post briefings, respectively). Although essential to the effectiveness of the training process, the emphasis placed on briefings varies considerably across training establishments. Furthermore, the capabilities provided as part of the training device/training system to assist in conducting effective briefings are often quite limited. Examples of capabilities to support briefing tasks will be provided later below under Training Assistance Technology.

Exercise development (Figure A-2), which precedes the conduct of training sessions, consumes a substantial portion of an instructor's time. This is a complex function wherein the instructor actually develops the training program and its supporting materials. It is complex in that it often requires the creative design of the course and its training exercises, with the instructor drawing upon the state-of-the-art in training methodology to achieve an effective training process. Whereas some capabilities, although usually quite limited, are often provided on the training device/training system to support exercise monitoring, control and briefing, usually little if any capabilities are provided to support exercise development. It is the exercise development function, interestingly, that determines how the training device will be employed within the training system. Examples of system capabilities to support exercise development are presented later under Training Assistance Technology.

Training system management, similar to exercise development, is typically an overlooked function of the instructor, and one with which he spends substantial time. A wide variety of tasks, issues, and considerations may be associated with training system management. Furthermore, each of these may depend on the particular training establishment under which the training device/training system operates. Nevertheless, several training system management tasks are common across training establishments, as indicated in Figure A-5. Perhaps the most important common set of tasks involves monitoring the effectiveness of training over time. For example, it is highly desirable to identify those training objectives (i.e., with associated exercises) that the typical trainees can readily perform upon entering the training program; and likewise to identify those training objectives (and exercises) that the trainees typically have substantial difficulty with, even near the end of the training program. Ideally, reduced emphasis would be placed on the former while increased emphasis would be placed on the latter training objectives in subsequent training programs. For another example, alternative training methods and training materials should be periodically evaluated to continually upgrade their quality and the effectiveness of the training process. These are major management tasks directly impacting the cost/effectiveness of training, and subsequently the operational readiness and effectiveness of weapon systems.

Each time a training exercise is run on the simulator valuable training performance data is generated. These data could be collected over time and used as the basis for the above evaluations, and other training system development activities. These data would be extremely useful to most levels of management for evaluation and planning purposes. Relatively little of these data are recorded and used today with regard to most training

device/training systems. This is one example of a set of training device/training system capabilities that could substantially augment training system management.

APPENDIX B

*SMARTTS SOFTWARE DESCRIPTION*

The SMARTTS software has three major parts: (a) the main body of SMARTTS software running on the SMARTTS host computer (VAX 11/780) with the VAX/VMS operating system; (b) SMARTTS modifications to the MSCG software to achieve the necessary interaction between the SMARTTS host computer and the MSCG; and (c) software modifications to the data gathering module of the MK117 fire control system to supply necessary information to the SMARTTS host computer. This appendix summarizes the 17 major parts of SMARTTS software running on the SMARTTS host computer comprising part one and the majority of SMARTTS functioning.

The high level SMARTTS/VAX System Control Configuration is illustrated in Figure B1, consisting of three major components. The SMARTTS system supervisor component (SY) creates, initializes and terminates subsystems; controls the system configuration; and logs and distributes alarms. The system supervisor component interfaces with a subsystem supervisor component which in turn controls the (a) model deck subsystem, which is off-line; (b) classroom subsystem supporting the instructor's console and displays; and (c) attack center subsystem supporting the instructor's console and two overhead displays. The subsystem supervisor creates and terminates all other components, implements operating state changes, and takes error recovery action. The model deck subsystem interacts via the model deck controller component. The classroom and attack center subsystems interact via the console controller component (i.e., instructor consoles). An overview diagram of these major components is presented in Figure B-1.

A brief description of each of the 17 major SMARTTS/VAX components follows:

System Supervisor -- Creates, initializes, and terminates the existence of all other SMARTTS/VAX software components. It includes monitoring the availability of all SMARTTS hardware components and partitioning SMARTTS hardware components among SMARTTS/VAX software subsystems. It is a collection of command files and programs that is responsible for setting up the system and invoking the subsystems.

Subsystem Supervisor -- A collection of subroutines that forms a process which is responsible for controlling a subsystem. It causes the creation, initialization, and termination of all software components that comprise a SMARTTS/VAX subsystem (i.e., there are three SMARTTS/VAX subsystems--model deck, classroom, and attack center subsystems). Each subsystem is comprised of a dedicated set of SMARTTS hardware resources together with facts-resident software components. Performance of the subsystem supervisor function includes monitoring and control of subsystem operating states. Each subsystem operating state determines a set of training assistance and operational features that may be utilized by an instructor or system operator. Performance of the subsystem supervisor function adjusts subsystem operations in response to hardware and software errors affecting the subsystems training assistance and operational capabilities.

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SY

- Creates/terminates subsystem
- Controls system configuration
- Logs & distributes alarms

SB

- Creates/terminates components
- Implements operating state changes
- Takes error recovery action

SC

- Monitors status
- System configurate control
- Subsystem control (VT-100)
- Service mode only hooks for generation and analysis modes (prototype)

CC

- Operating state (mode, exercise state)
- T/A feature control menus
- Both: scenario preview, exercise playback service modes
  ACS: Exercise control mode
  CRS: Monitor mode
- SMARTTS consoles (plasma & CRT) (1 classroom, 1 attack center)

SY  -- System Supervisor Component
SB  -- Subsystem Supervisor Component
CC  -- Console Controller
SC  -- System Controller
MDS -- Model Deck Subsystem
CRS -- Classroom Subsystem
ACS -- Attack Center Subsystem
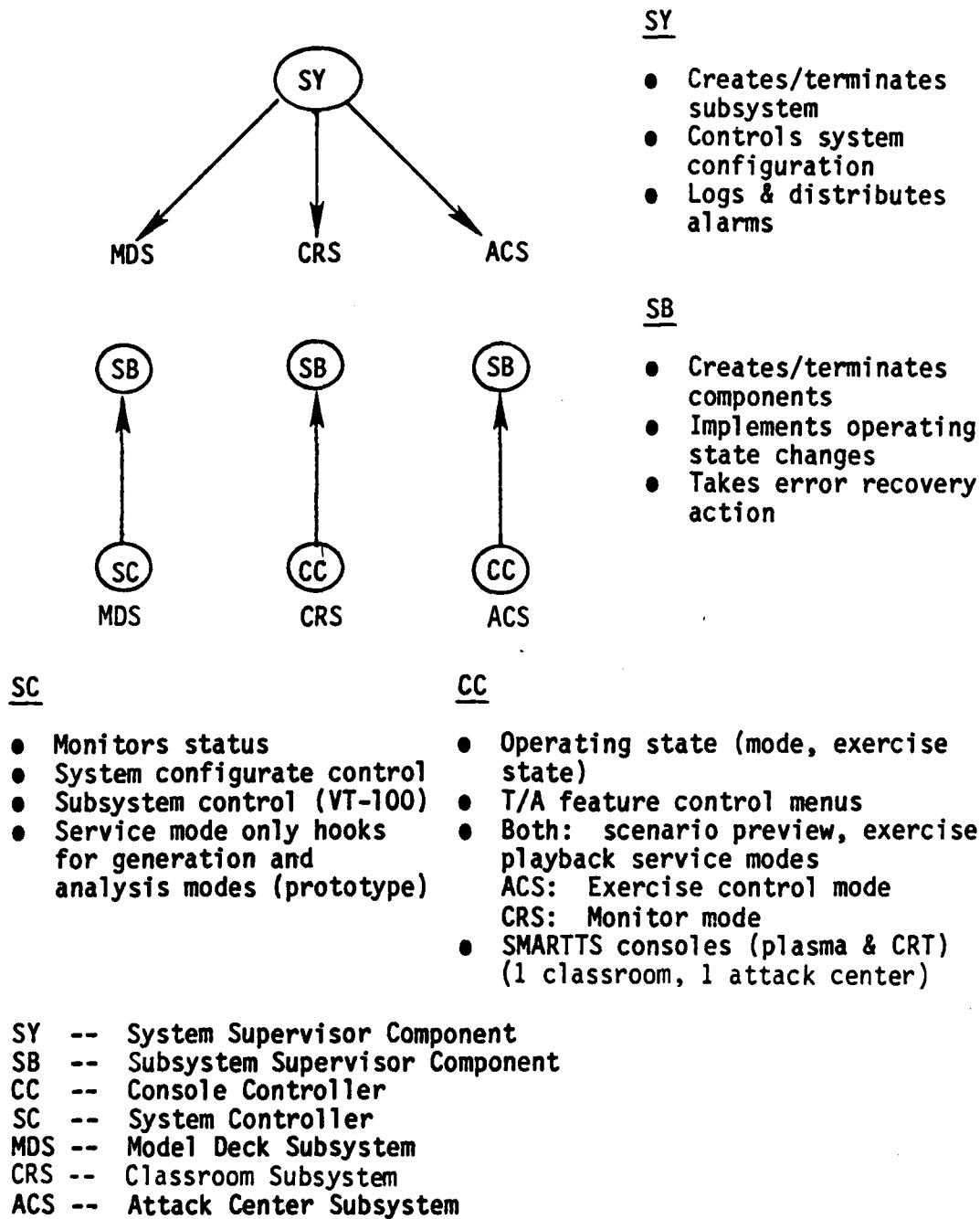
Figure B-1. Major SMARTTS/VAX system control configuration

Console Controller -- It enables instructors in the attack center subsystem and in the classroom subsystem to direct respective subsystem operations. The console controller communicates with the instructor by manipulating the instructors console plasma entry device. Upon receipt of instructor directions the console controller ascertains the validity of instructor directions and passes such directions on to other SMARTTS/VAX subsystem software components.

System Controller -- It allows the system operator, using the VAX VT-100, to direct model deck subsystem operations. The system supervisor accepts system operator directions, checks the validity of such directions, and forwards such directions to remaining SMARTTS/VAX subsystems software components.

Simulation Recorder -- It calculates and records the data for scenario preview or exercise control (i.e., ship movements and performance). The software is used in two manners: (a) as a separate process during scenario preview to record SMARTTS/VAX-based simulated exercise data, and (b) during exercise control to record MSCG-based real-time trainer exercise data. The exercise data is recorded to support the subsequent review of exercises in the attack center or in the classroom by trainee teams.

Review Controller -- It enables the instructor to retrieve and to replay previously recorded exercise data. It handles the opening of an old data base for replay during playback, handles the movement of time, and hence the moving of pointers in the data base.

Display Module -- It enables the display of information on the various color displays (i.e., instructor consoles, overhead CRTs in the attack center, and large screen display in the classroom). This component is subdivided into two major parts: (a) SMARTTS display format algorithm software, and (b) software that communicates with the display processor device. When these two parts are put together, they act as a process that controls a single color monitor.

Automatic Interactive Target (AIT) -- The AIT component is a collection of files that when linked together form the AIT target, providing means for automatic control of an MSCG target. Based on a set of characteristic specification determined by the instructor, the AIT function directs the actions of an MSCG target interactively with the MSCG ownship. The automatic interaction is dependent upon ownship actions and the target characteristics specification. The AIT controller is available during the combined SMARTTS/MSCG operation, as well as during standalone SMARTTS/VAX exercises.

Simulation Controller -- It coordinates the simultaneous executions of the SMARTTS/VAX and MSCG components during trainer exercises. It handles the control of the vehicle simulation when running in either scenario preview or exercise control (i.e., either joined with the MSCG, or decoupled from the MSCG). The simulation controller receives exercise data from the MSCG or from SMARTTS/VAX simulation calculation programs and forwards such data to the simulation recorder for storage in the recorded exercise file.

It reads and interprets the English-like script, and directs subsystem actions using the scenario profiles.

Alternative Tactics Calculator -- It projects the values of tactical variables and performance indicators during alternative tactics sessions. To accomplish this, it operates on data given to it by the console control, using the data calculator and data manager modules as necessary.

Data Manager -- This is the data base manager for the SMARTTS system. It includes an extensive data definition scheme. It is used by other functions to store and subsequently retrieve all relevant SMARTTS/VAX, MSCG, and MK117 exercise data. It is used by the simulation recorder to record trainer exercise data; the review controller to retrieve exercise data during exercise reviews; and the display module to present the exercise data.

Profile Manager -- It conducts the reading and rewriting (i.e., saving initial conditions) of the English-like script that is used to control the SMARTTS system. It causes scenario data to be recorded, manipulated, retrieved, and archived for future use. It allows the instructor to automatically initialize the SMARTTS/VAX system and the MSCG for a trainer exercise scenario. It also allows the instructor to lay out an exercise scenario prior to its execution, and to cause automatic execution of the exercise scenario. The simulation controller and the review controller utilize profile manager services to perform these functions.

Data Calculator -- It performs calculations to generate performance indicators on the basis of received data. It receives exercise data from the MSCG and MK117, uses that data to calculate the various parameters, and passes the calculated values to other software components for subsequent manipulation and recording. It also allows the SMARTTS/VAX system to execute simulated exercises (e.g., during exercise preview in the classroom) via simplified models in place of the MSCG and MK117 data (e.g., own ship maneuvers, sonar parameters, target motion analysis).

MK117 Communicator -- It handles all communications with the MK117 fire control system. Its function is to read data from the MK117 to translate that data from the MK117 UYK-7 format to VAX data format, and to relay the appropriate data packets to other SMARTTS/VAX software components.

MSCG Communicator -- It handles the communications between the VAX and the MSCG, translating the data for use by the MSCG or VAX as necessary.

Bulletin Board -- It is a data area that contains information relevant to the status of the entire SMARTTS system (i.e., subsystem operating states, hardware availabilities, and other globally known information). It stores this information and makes it accessible to all SMARTTS/VAX software functions.

Command Net -- It allows communication among SMARTTS software components by relaying commands from software components acting as command sources to software components acting as command sinks. It also contains the definitions and formats for all messages used in the system, thus enforcing command exchange protocols among SMARTTS/VAX software components.

System Services -- It contains a set of general purpose routines used by other modules, such as opening and closing files, coordination of intercomponent executions, and control access to shared and private computational facilities and resources.

## APPENDIX C
### SELECTED SMARTTS REPORTS
### DEVELOPED BY ECLECTECH ASSOCIATES, INC.

(H) <u>Hardware Maintainability Plan</u> (March 1981) - This document outlines the aspects of maintainability program management, equipment design, maintenance philosophy, sparing and documentation, organizational resources, maintenance activity monitoring, and general status reporting.

(H) <u>Maintenance Manual</u> (September 1982) - This document identifies the hardware elements of the system. It is also a guide to repair the SMARTTS system.

(H) <u>Trainer Engineering Report</u> (February 25, 1981) - This document contains initial design, performance and operational characteristics of the preprototype version of SMARTTS. It also defines how these characteristics and this preprototype version of SMARTTS will (a) interface with current SCST facilities at Norfolk, and (b) affect the SCST facility, the instructors, operators and trainees.

(S) <u>Data Base Design Document</u> (DBDD) (November 1982) - This document describes the SMARTTS data base and its format.

(S) <u>Integrated Logistics Support Requirements Report</u> (ILS Requirements Report) (February 1981) - This document identifies requirements and recommendations that will lead to the continuous improvement of SMARTTS operational capability and availability over SMARTTS' life cycle.

(S) <u>Interface Design Specification</u> (IDS) (October 1982) - This document shows data that is passed between the SMARTTS VAX and SMARTTS/MSCG.

(S) <u>Program Description Document</u> (PDD) (November 1982) - This document gives a listing of the SMARTTS document headers along with the source code.

(S) <u>Program Design Specification</u> (PDS) (November 1982) - This document gives the internal description of the SMARTTS software.

(S) <u>Program Performance Specification</u> (PPS) (July 1981) - This document describes the design of the SMARTTS system.

(T) <u>Instructor Course Instructor Lesson Guide</u> (November 1981) - This document contains lesson guides for each day of the SMARTTS instructor courses along with handouts for the course.

(T) <u>Instructor Handbook, Device Utilization Manual, Volumes I and II</u> (October 1981, Volume I and November 1981, Volume II) - Volume I contains instructional techniques. Volume II contains exercise lessons.

(T) <u>Maintenance Course Instructor Lesson Guide</u> (July 1982) - This document contains notes and course outlines for teaching the maintenance course.

(T) <u>Operator Course Instructor Lesson Guide</u> (May 1982) - This document contains notes and course outlines for teaching the instructor course.

(T) <u>Operator's Manual</u> (May 1982) - This document describes how to operate the SMARTTS system.

NOTE:   (H) = Hardware
        (S) = Software
        (T) = Training

ACRONYMS FOR SMARTTS

| | |
|---|---|
| AIT | Automatic Interactive Target |
| CMI | Computer Managed Instruction |
| CRC | Classroom Remote Console |
| IRC | Instructor Remote Console |
| ISD | Instructional Systems Development |
| KAST | Kalman Automatic Sequential Target Motion Analysis Technique |
| MSCG | Main Simulation Computer Group |
| NTEC | Naval Training Equipment Center |
| NWP | Naval Weapons Publication |
| PCO | Prospective Commanding Officer |
| PI | Performance Indicator |
| PXO | Prospective Executive Officer |
| SAT | Systems Approach to Training |
| SCST | Submarine Combat System Trainer |
| SMARTTS | Submarine Advanced Reactive Tactical Training System |
| SNR | Signal to Noise Ratio |
| SOAC | Submarine Officer Advanced Course |
| SOBC | Submarine Officer Basic Course |
| SOIC | Submarine Officer Indoctrination Course |
| TAT | Training Assistance Technology |
| TEF | Tactical Effectiveness Factor |
| TMA | Target Motion Analysis |
| TSA | Training System Analysis |
| TSET | Training System Evaluation Test |
| TSP | Time to Station |

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